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FIELD STUDIES OF APPLE TREE GROWTH AND FRUITING

III. SOME OBSERVATIONS ON THE MEASUREMENT OF TREE VIGOUR[1]

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INTRODUCTION

In the first paper of this series (42), methods of measuring the length and diameter of the terminal shoots were described. In the second paper (43), these measurements and other measurements of vegetative vigour were correlated with one another and with the percentage bloom and percentage set. It is now proposed to deal more specifically with tree vigour: to summarize the various methods that are in common use for measuring vigour, and to attempt to evaluate the usefulness of each method for this particular purpose. The discussion in this paper is based both on the findings reported in the first two papers of the series, and of the findings and opinions of other investigators.

The term "vigour" is used rather loosely by pomologists to denote that condition of the plant associated with rate of growth. In speaking of shoot growth, Chandler says that "by vigorous growth is meant growth that continues late in the season, the shoots being relatively long and the leaves large and of a rather deep green colour for leaves of the variety concerned" (9). From this viewpoint, the rate of growth may be considered a manifestation of the degree of vigour; and any method that proves satisfactory for measuring the rate of growth may be considered a satisfactory measure of the degree of vigour.

The close relationship between vigour and growth makes it necessary to define what is meant by growth. Speaking of plant cell development, Palladin (33) outlines three distinct stages of growth: first, division of the cell; second, enlargement of the cell; and third, thickening of the cell wall. The same division is given by Miller (31). It is pointed out that the external manifestations of growth are produced almost entirely by the second stage of these three. In some cases, cellular division may take place without any increase in size. Usually, however, the rate of growth of a plant can be determined more accurately by measuring the increase in size than by any other method. Thus Palladin points out that "Physiological studies of the growth rate of a plant are generally carried out by measuring the part in question. . . . In experiments of this kind only the external growth, or the enlargement of the plant, is measured, and the rate of enlargement is determined for a definite period of time and under a certain set of conditions" (33). Maximov (29) expresses the same

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opinion. Increase in size obviously means increase in weight. Barton-Wright explains that "It was early shown by Sachs that the only true criterion of growth is increase in dry weight. . . . Estimation of dry weight however, has the disadvantage that the plant is killed. . . ." (2).

The question arises as to whether the term "vigour" should be applied to the rate of growth of the whole plant, or to that of a part of the plant only. The total growth includes both vegetative growth (wood, bark, leaves) and reproductive growth (blossoms, fruit). It is to vegetative growth more particularly that the horticulturist commonly applies the term vigour. Thus Kraus and Kraybill (24), Harvey (18), and Roberts (36) make a definite distinction between vigour and the tendency to reproduce.

In this paper, the following conception of vigour is used as the basis of discussion: Vigour is an expression of the activity of the cells of the meristem or growing parts of the plant. The more active the cellular division and enlargement, the greater the vigour. The greater the vigour, accordingly, the greater is the increase in the size of the plant in a stated period of time; and as a corollary, the vigour may be measured by determining the total increase in size in a stated period of time in relation to its size at the start of this period. Thus in the apple tree, a satisfactory measurement of vigour will be one which represents the ratio of the new annual growth of wood and bark to the total amount of meristem (cambium layer and growing points) at the start of the year. Vigour is used in the sense of vegetative vigour only.

METHODS OF MEASURING VIGOUR

A large number of different methods have been used by pomologists to measure or to classify tree vigour. Some methods involve actual measurements of increase in growth, some merely observational evidence. The specific purpose to be accomplished may be to assist the orchardist to determine his fertilizer or pruning requirements; or it may be to record the effects of experimental treatments on tree vigour. This latter purpose is the one that will be stressed in the following discussion. It is proposed to deal more especially with those methods of measuring vigour that have been most commonly advocated by pomologists.

Increase in Height and Spread of Tree

Though many investigators have recorded the height and spread of the tree, few appear to have used these measurements as expressions of vigour for the comparison of the results of experimental treatments. Hoblyn states that "Measurements of height and spread . . . . are useful as indications of the relative vigour of the trees after a period of years and especially as a demonstration to the grower of the space taken up by the tree. As measurements of annual increment they are of little value, being greatly affected by the cropping of the tree, ... as well as by such operations as pruning and setting up of the trees" (20). Blake and Davidson (4) object to the use of tree height or spread as a measurement of vigour because although they may indicate quantity of growth they do not indicate quality of growth. The measurements taken by the author corroborate the above contentions. In addition, it has been found that once trees start to crowd in the orchard, the measurements of height and

spread are useless as indicators of vigour. They may of course be used for the determination of tree volume. They have also been found very useful for comparing differences in the type of growth of young trees, such as trees of different varieties, or of the same variety on different stocks (14).

Increase in Trunk Circumference

The increase in trunk circumference and the terminal length appear to have been used more than any other measurements for the purpose of determining differences in vigour in apple trees. Of the two, the former has been found the easier measurement to record. Collison and Harlan point out that "There seems to be a general opinion based in part on experimental work that trunk diameter is perhaps the best measure of growth and vigour." (11). They then show that the general increase in tree size is, over a period of years, reflected in the increase in trunk size. Sudds and Anthony (38) conclude that trunk and branch circumference are usually the only records that need to be taken in studies involving apple tree vigour. On the other hand, Bradford and Joley point out that "Trunk girth measurements . . . . have inherent limitations in the relatively great importance of small errors in measurements as well as difficulties of execution due to trunk eccentricity, sunscald, wounds, proximity of scaffold limbs, etc." (7). Certain treatments have also been found to affect the increase in trunk circumference in one way and other parts of the tree in another way. Thus Bedford and Pickering (3), Tufts (40), Chandler (8, 9), Knight (22) and others have found that heavy pruning has increased the annual shoot growth but has decreased the annual thickness of trunk growth, in comparison with light or no pruning. Hoblyn and Bane state that "It is possible for one manurial treatment apparently to produce an increase in stem cross section without a corresponding increase in shoot growth." (21).

A study of the trunk circumference records taken during the past six years on the Kelowna Project has shown (*a*) that over a period of two or more years the increase in trunk circumference has been as reliable a guide to the trend of vigour as has any other one measurement; (*b*) that at least until the trees have become badly crowded, this reliability has been influenced little if at all by the increase in tree size; (*c*) that in any one year it has not been satisfactory by itself, since on biennially-bearing trees it has shown a decrease in the same year that the terminal length has shown an increase (43); (*d*) that pruning and certain other treatments have had differential effects on increase in trunk circumference and on terminal length (to be reported in the fourth paper of this series); and (*e*) that great care needs to be exercised in the choice of the position of measurement, in the permanent marking of this position, and in the scraping off of the loose bark to the same degree in all cases. As the tree has become larger, the annual increase in trunk circumference has tended to lessen, but so also has the terminal length (43). However, when the trees have become so crowded that more severe pruning has become necessary, the differential effects of pruning noted above have been found.

Increase in Cross-sectional Area of Trunk

If any method could be found for measuring accurately the size of the tree, this method could be used to determine the total differences in size from year to year. From these in turn could be calculated the ratio

of increase in any specified length of time. It is of course impossible actually to measure tree size or weight without destroying the tree, but this does not preclude the possibility of there being some measure closely enough correlated to tree size to represent it with sufficient accuracy. As already noted, the increases in height and in spread of the tree are of little value for this purpose after the tree has commenced to bear.

The cross-sectional area of the trunk has been suggested as a relative measure of tree size. Working with two-year-old walnut, almond and peach trees, Tufts (40) obtained very high correlations between trunk circumference and weight of both root and top. Heinicke (19) found that the weight of young apple trees increased much more rapidly than did the trunk circumference. Sudds and Anthony (38), also working with young apple trees, found a correlation of +0.92 between the trunk circumference and the weight of the top of the tree. In a study of the branches, they found that substituting the cube of the circumference for the circumference increased the correlation with weight. Both the square and the cube of the trunk circumference gave higher correlations with yield than did the circumference itself. This last result was also obtained by Hoblyn (20). Working with bearing apple trees, Collison and Harlan (11) obtained a correlation of +0.972 between trunk circumference and weight of top. Smith, Kinnison and Carns (37), in studies of young grapefruit trees, obtained correlations of +0.989 and +0.981 between the area of trunk cross-section and the weights of the tree above and below ground respectively. Working with young apple trees, Knight and Hoblyn (23) found that the ratio of weight of scion to cross-sectional area of trunk increased as the tree increased in size. They pointed out that since the total cross-sectional area increases cumulatively from the trunk to the young shoots, the area at the trunk cannot be expected to represent accurately the total weight of the top of the tree when trees of different size are used.

Any factor that influences the increase in trunk circumference influences in like manner the increase in cross-sectional area of the trunk. It was noted above that the increase in trunk circumference and the terminal length have been shown to be affected in different manner by biennial bearing, by pruning, and by fertilizer treatments. When the trees are biennial bearers, accordingly, or when they are subject to wide variations in severity of pruning or in fertilizer treatments, care needs to be exercised in the use of either the increase in area of cross section or the increase in trunk circumference. This is especially true when comparisons are being made annually. On the other hand, the size of tree alone has been found in the Kelowna Project investigations to have little if any differential effect on increase in trunk circumference and terminal length. These results have been obtained with trees varying in trunk circumference from less than 25 to over 100 cm. They are not necessarily at variance with those noted above of Knight and Hoblyn (23), since the ratio of weight of new growth to total weight of top decreases at the tree grows older.

As was explained in the Introduction, the conception of vigour used in this paper is that vigour is that condition in the plant that is associated with the rate of cell division and enlargement. The actual enlargement of the plant during a specified length of time obviously depends both on

cellular activity and on the number of cells taking part in the process of growth. The latter is represented in the plant by the meristem—*i.e.*, the cambium layer and the growing points. If it were possible to measure in some simple manner the area of the cambium layer, and to measure also the volume of new wood and bark laid down by this layer in one year, the ratio between the two measurements would represent the rate of growth, or vigour. In a cross section of the trunk, the former measurement is represented (roughly) by the circumference at the start of the year, the latter by the increase in area. Dividing the increase in area by the circumference gives a very close approximation to the increase in radius. This in turn bears a constant ratio of 1 : 2 to the increase in diameter, and of 1 : 6.283 to the increase in circumference. The discussion of this sub-section, accordingly, leads to the same point as that of the above sub-section—*i.e.*, that the increase in trunk circumference appears to be a reliable measure of the thickness of the new annual ring of wood laid down each year over the tree as a whole.

Terminal Length

The annual shoot growth of the tree has been recorded by investigators in either one of two general ways: as total shoot growth on the whole tree, or as average shoot length per tree. The former method has been used more especially with young trees. As the trees have increased in size, the recording by this method has become too laborious, and some system of sampling has been found necessary. Blake and Hervey (5) reported this difficulty with peach trees, and Hoblyn (20) with apple trees. In any case, it is obvious that the total shoot length cannot be used as an expression of vigour without correcting in some way for differences in size of tree.

The average length of shoot growth has been accepted by many pomologists as being indicative of tree vigour. Thus Chandler (9) points out that the increase in shoot growth accompanying pruning is an evidence of increased vigour; though he explains further that pruning may cause the tree as a whole to increase less rapidly in size. Bradford says that "The performance of the shoots is perhaps the best single index, though no one part of the tree should receive exclusive attention. The figures submitted in this paper indicate that vigorous condition of the shoots implies a vigorous condition of the spurs; if the shoots are making good growth and forming new spurs freely, the remainder of the tree may be presumed to be in good condition." (6). While admitting the value of shoot length as a measure of vigour, Roberts (35, 36) points out that length is not sufficient, that the diameter of the shoot is just as important. He emphasizes that the diameter is of value as a measure of the quality of growth as well as of its quantity. Blake and Davidson (4) object to the use of the terminal length on these same grounds. Bradford and Joley (7) point out that there is a great deal of variation in the shoot length on any one tree, and that the average of a sample must accordingly be used with caution. They submit a chart for use in changing the terminal length on Delicious trees into terminal weight. Their method appears to take no account of the effects of biennial bearing on the weight of the terminal per unit of length. As already noted, pruning and certain other treatments have been found to affect the terminal length and the increase in trunk circumference in different manner.

The investigational work in the Kelowna Project orchard during the past six years has led to the following generalities with respect to terminal growth: (*a*) The method of sampling used, as outlined in the first paper of this series (42), appears to have proved quite satisfactory. It is simple and has taken comparatively little time per tree. The method of choice has reduced the variability within the sample. And the restriction to one type of terminal has ensured that a degree or condition of vigour has been represented rather than total growth. (*b*) The cumulative terminal length over a period of two or more years appears to have been a reliable guide in most cases to the trend of vigour. (*c*) In any one year, however, it is not satisfactory by itself. On a biennially-bearing tree, the terminal length has usually been less in the off year than in the on year, while the reverse has held true for such other indications of vigour as terminal diameter per unit of terminal length, increase in trunk circumference, and leaf area. (*d*) Pruning and certain other treatments have had differential effects on terminal length and on increase in trunk circumference.

The use of the terminal length has this disadvantage, that it takes more time to measure and to record than does the trunk circumference. On the other hand, the terminal growth for any one year can be recorded all at one time, whereas the trunk circumference must be recorded both before growth starts and after it stops in order to determine the annual increase. In certain experiments, then, the terminal length is to be preferred. In any case, it appears to be somewhat easier to use than is the increase in trunk circumference as a basis for making pruning or fertilizer recommendations to fruit growers.

Terminal Diameter

As noted above, the recording of the terminal diameter has been advocated (35, 36) as a measure of the quality of growth in contrast to its quantity. It appears that a large number of investigators have indeed been using it for this purpose. By "quality" here is meant the ratio of diameter of terminal to length, where the terminals are of the same length. This ratio has been found to bear a definite relationship to fruitfulness. Roberts (36) showed that the amount of stem thickening, the spur thickness, and the terminal thickness in relation to length were all greater on those trees or limbs that produced a higher percentage of fruit buds. In any case, if the rate of increase in size or weight of the tree is accepted as a measure of vigour, the thickness of the new growth must (for this purpose) be equally as important as its length, irrespective of fruitfulness. In fact, this must hold true with respect to all the new growth on the tree.

In the first paper of this series (42), it was pointed out that the diameter of the terminal is affected both by the length of the terminal and by those factors that influence the increase in trunk circumference. It was recommended that if the effect of terminal length is to be eliminated as much as possible, the diameter should be measured close to the tip. High correlations were found between the terminal diameter and both the terminal length and the increase in trunk circumference. Similar findings were reported in the second paper (43).

The question arises as to whether, if the increase in trunk circumference is being determined, there is any real value in recording the terminal diameter also. The former appears to be the more closely associated with

the thickness of the new annual ring laid down over the tree as a whole. As noted above, the increase in cross-sectional area of the trunk is in most cases a very good measure of the increase in tree size both above and below ground. In so far as the relation of growth to fruitfulness is concerned, it may be noted that the author has already reported in the second paper of this series (43) that he has found the percentage bloom in any one year to be more closely correlated to the increase in trunk circumference of the previous year than to the terminal diameter at the base.

The usefulness of any particular measurement employed to characterize a variable factor or condition depends to some extent on the range of values that it gives in relation to the mean value. The greater the range, the more accurately can any one value be allocated to a particular part of that range. In Figure 1 are shown the relative rates of change from tree

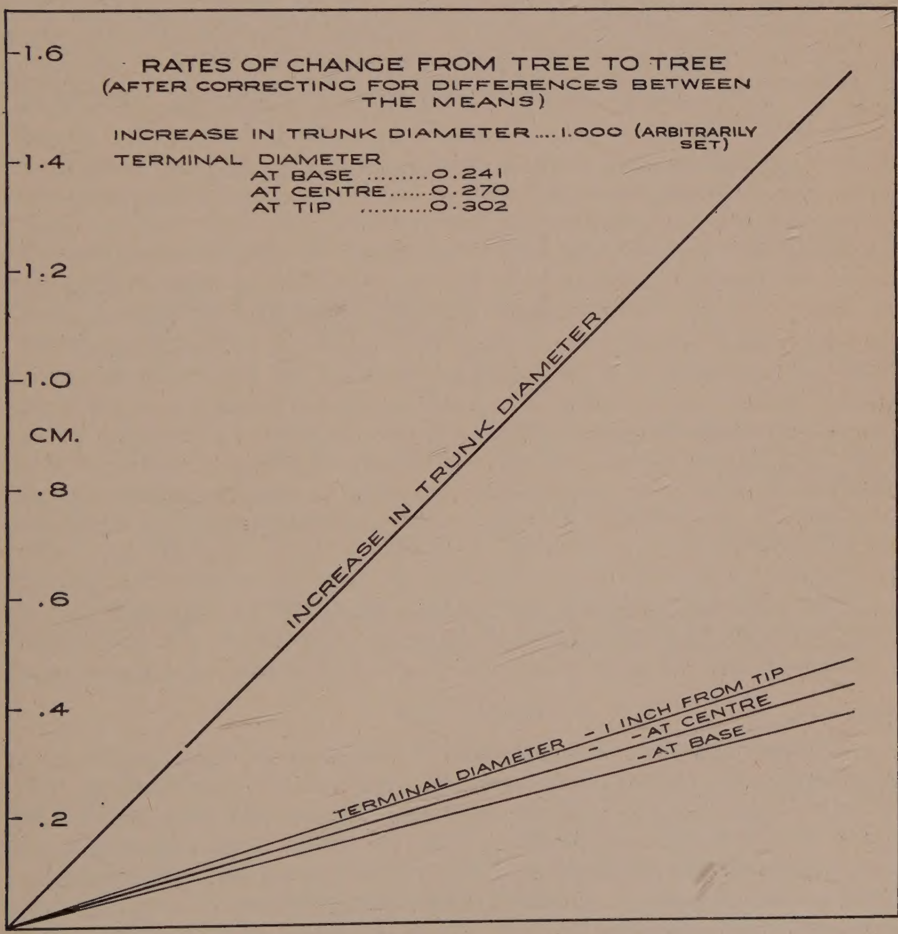

FIGURE 1. Comparative rates of change from tree to tree in the increase in trunk diameter and in the terminal diameters at the base, centre, and one inch from the tip, when the values of the respective distributions are arranged in increasing order. The method of calculating these rates of change is given in Table 1. The data on which this chart is based are from measurements taken on fifty check-plot McIntosh trees in the fall of 1936.

to tree of the terminal diameters as measured at three different positions, and of the increase in trunk circumference, on fifty McIntosh trees. The slope of the line representing the increase in trunk circumference has been given an arbitrary value of 1.0, and the slopes of the other three lines arranged accordingly. The method of calculating these slopes is indicated in Table 1. It will be noted that the increase in trunk circumference showed a rate of change (and hence a total range) over nine times as great as did the terminal diameter at one inch from the tip; and that when correction was made for the differences between the means, its rate of change was still over three times as great. It will also be noted that correcting for the means changed the order of the rate of change at the base, centre and tip of the terminal. The corrected rate for the increase in trunk circumference was (obviously) the same as that for the increase in trunk diameter. From the viewpoint of rate of change or range of distribution, it would seem that the increase in trunk circumference is much to be preferred to any one of the terminal diameters. Indeed, where the terminal length and the increase in trunk circumference are being recorded, there appears to be no real need for recording the terminal diameter as well.

Table 1.—Calculation of the rates of change of the increase in trunk circumference and of the terminal diameters at the base, centre, and one inch from the tip

——	Mean	Standard deviation	Rate of change*	Rate of change div. by Mean	Corrected rate of change†
	cm.	cm.			
Increase in trunk circumference	2.510	1.116	3.142	1.252	1.000
Increase in trunk diameter	0.799	0.355	1.000	1.252	1.000
Terminal diameter					
at base	0.576	0.047	0.174	0.302	0.241
at centre	0.325	0.032	0.110	0.339	0.270
at one inch from tip	0.288	0.030	0.109	0.379	0.302

* This represents the comparative rates of change from tree to tree when the trees are arranged in order of increasing values. It is calculated from the slopes of the lines of trend of the distributions formed by plotting the increase in trunk diameter against the respective terminal diameters. The rate of change of the increase in trunk diameter has arbitrarily been given a value of 1.0.

† This column represents the rate of change after correction has been made for the difference in means.

Spur Growth

The spur growth has been studied in some detail by a large number of investigators, and has been found to bear a close relationship to fruitfulness. Thus Yeager (44), Auchter (1), Roberts (34, 36), Mack (25), Mecartney (30), Dorsey and Knowlton (13), and Tucker and Potter (39) have reported that the formation of fruit buds is related to the length of the spur, to its diameter, or to both. In no case, however, is any suggestion made that the growth rate of the tree as a whole should be measured by means of the spurs. Mack (22) found no constant correlation between spur growth and terminal growth. Bradford (6) found difficulty in distinguishing between the longer spurs and the shorter shoots. Vyvyan and Evans (41) pointed out the necessity for sampling each type of spur growth

separately, if any adequate conception is to be gained of the differences between trees. The author has found the same to hold true. Any method of sampling that would give a good average for the tree as a whole would be too laborious for practical use. Moreover, there is no indication that this average would provide a reliable measure of either tree vigour or fruitfulness.

Leaf Area

Both the total leaf area and the average leaf area have been used for a variety of purposes, such as in studies of fruitfulness, of fruit size, of fruit colour, and of tree vigour. Gourley (15), Auchter (1), Harley (17), and Roberts (36) have shown that an increase in leaf area is usually accompanied by an increase in fruit bud production. Haller and Magness (16), Magness (26), and Magness, Overley and Luce (27, 28) have demonstrated that the leaf area per apple influences the size and quality of the fruit.

The leaf area appears to constitute an indirect indication of tree growth. Chandler (9) points out that where the growth is vigorous, the leaves are large and of a deep green. Roberts (36) found that large leaves were associated with a large diameter of shoot or spur in relation to its length. Claypool (10) reported that a decrease in the size or efficiency of the leaves had been found to be reflected in a lessened increase in trunk circumference. Overholser and Overley (32) reported that with trees of approximately the same size, a greater leaf area per tree was accompanied by longer terminal shoots. As noted in the second paper of this series (43), the author has found the leaf area per unit length of terminal to be positively correlated with the diameter of the terminal.

Some difficulty has apparently been encountered by different workers in the development of a method of sampling and measuring the leaves that can be applied in routine experimental work. This is due to the fact, as pointed out by Vyvyan and Evans (41) and by Blake and Davidson (4), that there is so much variability in the leaf size on the one tree. However, it may be possible to overcome this difficulty by a deliberate selection of leaves similarly situated in all cases. Thus Blake and Davidson (4) have classified Delicious leaves from selected spurs, and Collison and Harlan (12) have used the five largest leaves on each of ten selected terminals per tree. In preliminary work in the Kelowna Project orchard, the author has found a modified form of Collison and Harlan's method to be apparently quite satisfactory.

DISCUSSION

There does not appear to be any one measurement for tree vigour that is infallible. In most cases, it seems advisable to take at least two types of growth records on every tree, if the effects of differential treatment on tree vigour are to be clearly portrayed. The actual records to take will of course depend largely on the purpose to which they are to be put. Thus if the experiments are for demonstrational purposes only, it may be sufficient to take simple records of terminal length and diameter, or of leaf area and colour. In most experimental work, however, it is advisable to choose the types of records to be taken with some care. One question that each investigator must answer for himself is whether the measurements are to represent both quantity of growth and its relation

to fruitfulness, or just the former. Thus he might depend on the increase in trunk circumference or the terminal diameter to give him information with regard to both vigour and fruitfulness. However, there are more direct methods of measuring fruitfulness than these—i.e., percentage bloom, percentage set, and crop of fruit—and in ordinary routine work the use of measurements of vigour for this purpose appears to be quite unnecessary.

The conditions under which the experimental work is being conducted will have some bearing on the preference for the measurements to be taken. In a one-year or part-year test, for example, the increase in trunk circumference may not be as valuable as the terminal or leaf measurements. Considerations of economy and of time requirements usually make it advisable to confine the types of measurement to as few as are necessary to give the required information in a broad way.

For routine field plot experiments, it is suggested that at least the increase in trunk circumference and the terminal length be recorded. To a large extent, the weaknesses of each are offset by the strength of the other—such for example as in the case of the effects of biennial bearing or of pruning. In addition, records of leaf area are usually found quite informative. Where the pruning is uniform, and where long-time trends only are desired, the annual increase in trunk circumference may be sufficient. Where this measurement cannot readily be taken, a combination of terminal length and terminal diameter should prove valuable; and in such a case, it would seem that the diameter at 1 to $1\frac{1}{2}$ inches from the tip is preferable to that at any point closer to the base.

Although either the increase in trunk circumference or the terminal length provides a fairly satisfactory measure of vigour over a period of years, neither one is sufficient by itself as a numerical specification of the growth of a tree in any one year. However, a combination of the two appears to be quite satisfactory for this purpose. The method used by the author has been to multiply the average terminal length by the increase in trunk circumference, giving a figure called the "growth index". This figure represents the combined activities of the cells in the cambium layer and of those in the growing tips. It is used primarily as an indication of vigour, and is only applied to fruitfulness when it is desired to study the relationship of fruitfulness to vigour. Examples of the effect of biennial bearing on the growth index are given in Table 2. In spite of a longer

TABLE 2.—EFFECT OF BIENNIAL BEARING ON THE GROWTH INDEX

Tree No.	Record	1932	1933	1934	1935	1936
N28*	Percentage bloom	85.0	33.0	83.0	10.0	91.0
	Increase in trunk circ., cm.	3.1	3.2	1.8	3.6	2.4
	Terminal length, cm.	14.5	20.4	29.3	27.2	33.3
	Growth index	44.9	65.3	52.7	97.9	79.9
J18	Percentage bloom	3.0	93.0	5.0	93.0	11.0
	Increase in trunk circ., cm.	3.2	2.1	2.9	2.0	2.6
	Terminal length, cm.	14.4	18.1	13.2	17.8	17.3
	Growth index	46.3	38.0	38.3	35.6	45.0

* Tree N28 is a Delicious, and J18 is a Jonathan.

terminal growth in the on year, the vigour of the tree as a whole has usually been somewhat less that year than in the off year. In fact, a significant negative correlation has been found between the growth index and the percentage set of fruit in the same year. The immediate reason for this is that the negative correlation between the increase in trunk circumference and the percentage set has been higher than the positive correlation between the terminal length and the percentage set (43). The growth index will be used in the fourth paper of this series as a measure of the effects of plot treatment on tree vigour.

SUMMARY

The following field measurements of tree vigour are discussed: increase in trunk circumference, increase in cross-sectional area of the trunk, terminal length, terminal diameter, spur growth, and leaf area. It is pointed out that no one measurement is infalliable. Biennial bearing and pruning have been found to affect the increase in trunk circumference and the terminal length in different manner.

It is suggested that in routine field plot work, at least the trunk circumference and the terminal length should be recorded each year; though for general trends over a period of years, the increase in trunk circumference may be found sufficiently reliable. In addition, records of leaf area should prove of value. If the terminal diameter is recorded, it is suggested that it be taken close to the tip.

A measure of vigour that has been found satisfactory is the "growth index", obtained by multiplying the annual increase in trunk circumference by the average terminal length.

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Résumé

Études de la végétation et de la fructification du pommier. IIIe partie. Quelques observations sur la mesure de la vigueur des arbres. J. C. Wilcox, station expérimentale fédérale, Summerland, C.-B.

L'auteur discute les mesures suivantes de la vigueur de l'arbre: augmentation de circonférence du tronc, de la section transversale du tronc, diamètre terminal, longueur terminale, pousse de l'éperon et superficie des feuilles. Il fait remarquer qu'aucune mesure seule n'est infaillible. On a constaté que le rapport bisannuel et la taille affectent d'une façon différente la croissance du diamètre du tronc et la longueur terminale. L'auteur prétend que la circonférence du tronc et la longueur terminale devraient être notées tous les ans; cependant, comme indication générale pendant une série d'années, la circonférence pourrait être une information assez exacte. En outre, l'observation de la superficie des feuilles devrait avoir quelque utilité. Si l'on note le diamètre terminal, on propose que les mesures soient prises près de la pointe. Une mesure de vigueur qui a été trouvée satisfaisante est l'indice de la pousse, que l'on obtient en multipliant l'augmentation annuelle de la circonférence du tronc par la longueur terminale moyenne.

A STUDY OF THE EXTENT TO WHICH APPLE ORCHARD CULTIVATION MAY BE REDUCED

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[Received for publication June 1, 1937]

The question of how much cultivation is required for the greatest economy in fruit production has long been a contentious one. Originally orchards were mainly in sod, but under sod "neglect" rather than the present accepted system of sod culture where attention is given to the sod, *i.e.*, sufficient nitrates and other fertilizers applied to compensate for the amounts used by the sod. After experiments had shown that the cultivation of neglected sod orchards gave almost instant tree response a system of orchard tillage became nearly universal.

Early records indicate that tillage was continued until about mid-August when a cover crop was sown. The main purposes of such a crop was to check the lush growth of the trees, ripen the wood for winter, utilize the readily leached soil nutrients, particularly nitrates, and to cover the ground for winter. It was observed by some that the first flush of tree response to cultivation, particularly on certain soils, soon wore off and the objection was raised to this system of almost continuous cultivation that the soil would become "burnt-out". The advocates of cultivation maintained there was no such danger, providing, of course, that a cover crop was used with tillage.

Unfortunately cover crops sown about Aug. 15th did not maintain the organic content of the soil to a sufficient degree. Gradually the seeding date of this cover crop—now recognized as a green manure crop—has been advanced, until July 1st is now accepted in many localities as the date when tillage should cease and a green manure crop be sown. In certain seasons and on certain soils even this change of date does not always permit sufficient growth of green manure to maintain the soils in a high state of fertility. Would it be advisable to cease tillage and to seed still earlier and thus permit greater growth of green manure crops?

In 1928, an experiment was commenced at the Ontario Horticultural Experiment Station in an endeavour to answer this question. A 6-acre block of apple trees planted in 1920 was selected for a comparative test of a minimum period of cultivation against the more orthodox method of cultivating until July 15 and then seeding to a green manure crop.

This six acres was originally divided into eight plots to include, in addition to the minimum and regular cultivation, early and late plowing treatments. Early plowing was done as early as the soil could be worked. Late plowing was to be done at least two weeks later. The object of this plowing difference was to obtain if possible some information on the effect of allowing over-wintering green manure crops to grow in the spring. As few over-wintering crops have been grown the differences were not marked. All plowing is now done early.

[1] Assistant in Hardy Fruits.

TABLE 1

Plots	Treatment	Number of trees of each variety in each plot				
		Baldwin	McIntosh	Spy	Wealthy	Duchess
1 and 2	Minimum cultivation	15	10		52	4
3 and 4	Regular cultivation	12	8		40	3
5 and 6	Regular cultivation		5	15		43
7 and 8	Minimum cultivation		4	12		33

Most of the Duchess and Wealthy trees were removed in the fall of 1935 which marks the completion of one phase of the orchard's development of which this paper is a record.

The orchard therefore was made up of Baldwin, McIntosh and Spy planted 39 feet × 39 feet with Duchess and Wealthy as fillers. The land, nearly level, is classified as Vineland fine sandy loam (imperfectly drained, brown sandy loam, underlain with clay. Fair organic matter and medium acid. O.A.C. Chemistry Dept.). Originally it had been part of a grain farm but for several years before being taken over by the Experiment Station was rented to an absentee tenant and badly neglected. This area was low in organic matter and like most of the old lake bottom soils of the Niagara district was very low in minerals, particularly phosphorus and potassium.

In 1934 and 1935 applications of superphosphate and sulphate of potash were plowed under in the following quantities in pounds per acre.

	20% superphosphate	*50% sulphate of potash*
1934	600	250
1935	500	125

Even after these additions the level of readily available phosphorus and potassium is very low as shown by July 1936 determinations:

Soil depth in inches	Phosphorus (p.p.m.)		Potassium (p.p.m.)	
	Minimum cultivation	Regular cultivation	Minimum cultivation	Regular cultivation
0– 6	31	20	15	15
6–12	37	30	5	5
12–18	65	57	5	5

Between 1920 and 1928 the whole orchard, except for some minor spray variations, received the same treatment. The accompanying charts show the uniformity of the trees in 1922 and again in 1927, the autumn before the experiment began.

PLAN OF EXPERIMENT

The cultural treatments were as follows. The whole orchard was plowed in the spring. Half of the plots were worked just sufficiently to prepare a good seed bed, and a green manure crop was sown. In one very

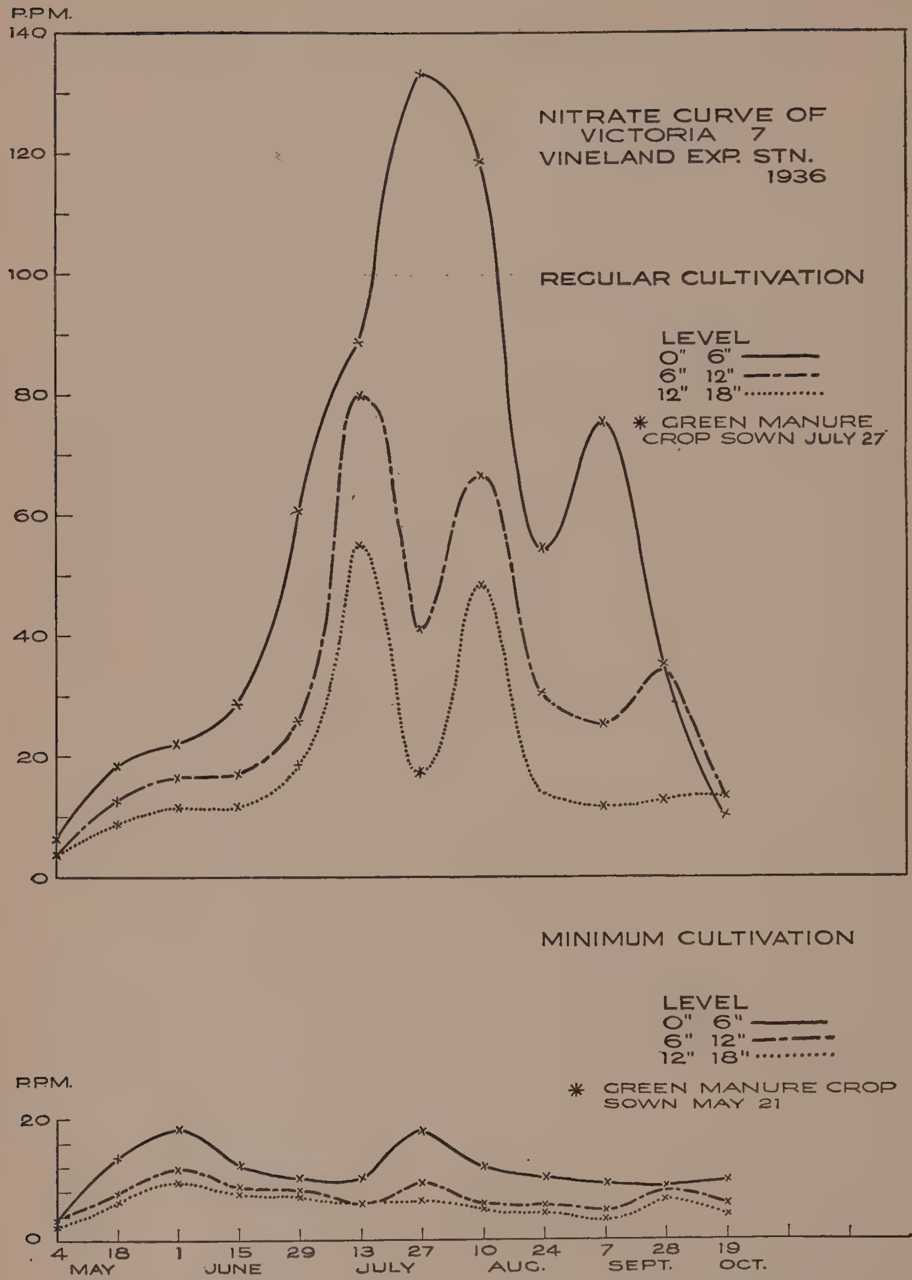

FIGURE 1. Nitrates in p.p.m., based on dry soil, under regular and minimum cultivation treatments in 1936.

early season the green manure crop was in by April 30. Another year when some extra cultivation seemed necessary to destroy weeds the green manure crop was not sown until early June. In most years the crop was sown about May 15. The remaining half of the plots were cultivated

until July 15 and then seeded. One-half, therefore, received roughly two months more cultivation each year and consequently had two months less time in which to produce green manure.

Each year the green manure crop was the same for all plots but has varied greatly over the period. Where a long season crop such as clovers, soy beans, rape, etc. was used, only one seeding was necessary. Where crops like buckwheat were used, two successive crops were necessary on the minimum cultivation plots. In this case the second seeding on the minimum cultivation plots was done at the same time as the one and only seeding on the regular cultivation plots.

The following records have been kept for this experiment—

Diameters. Since the fall of 1922 trunk diameters have been taken annually. These are shown in Figure 2.

Yields. Records of yield are kept for each tree in pounds.

Soil Moisture. Since 1931 soil moisture samples have been taken weekly at 0–6″, 6–12″ and 12–18″ depths from early June to mid-October or later. During 1936, however, these samples were taken every two weeks from May 4 to October 19.

In this year in addition to the moisture tests, nitrate determinations were made; 16 samples were taken from each of the eight plots and this composite was analysed in duplicate. The effect of minimum and regular cultivation on nitrate supply is illustrated in Figure 1.

RESULTS

It did not always follow that the two seedings of a green manure crop made double the growth of the single seeding because in the very dry years of 1934 and 1935 when we had a total precipitation of 24.5 inches and 24.0 inches (normal, 21 yr. mean, is 28.8 inches) the second seeding on the minimum cultivation plots grew poorly as compared with that on the summer-fallowed July 15-seeded plots.

Foliage and Fruit Colour

The difference in green manure crop growth was also reflected in tree appearance in those two years. Towards autumn the trees in the minimum cultivation plots had a much lighter foliage. In 1935 particularly, the crops of Duchess and Wealthy on these plots matured somewhat earlier and had a decidedly higher colour than had the apples from the plots receiving regular cultivation.

During 1934 and 1935, the two dry years, the foliage differences noted above were pronouned. This was the first time since 1928 that any differences could be observed. In 1928 following a very heavy midsummer rain the minimum cultivation plots retained a good foliage colour while the trees on the regular cultivation plots became pale.

The 1934 and 1935 differences in foliage colour were thought to be due to possible moisture deficiencies, but a tabulation of moisture data taken weekly at 6 inches, 12 inches and 18 inches depths, during the growing seasons of 1931–35 inclusive, failed to indicate any appreciable differences between plots.

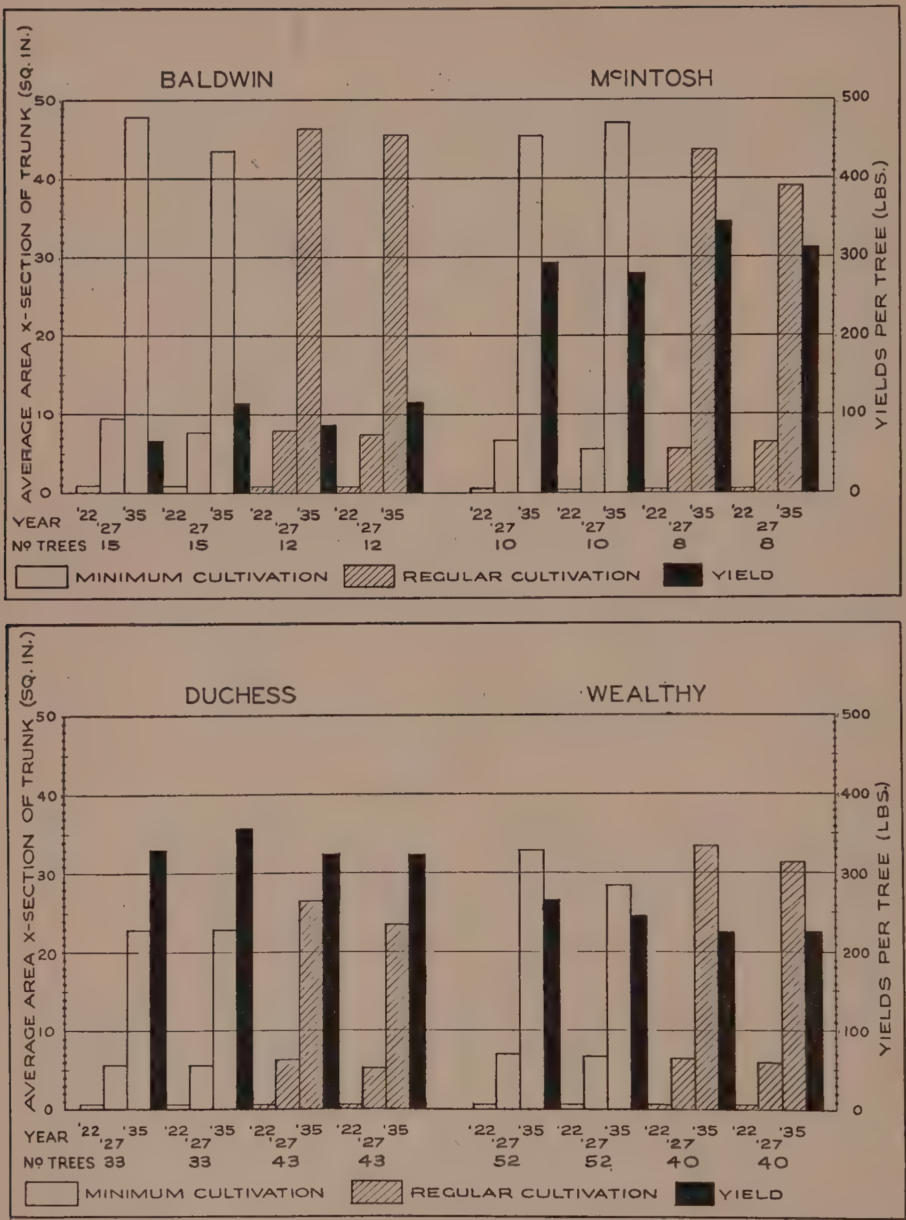

FIGURE 2. Average size of tree and average total yields. Average size of tree is shown for the fall of 1922 when first taken, in the fall of 1927 just before the experiment began, showing the uniform growth of the trees to that time, and in the fall of 1935 when the most of the fillers had to be removed. Yields are from 1928–1935 inclusive and are shown in black for their respective plots.

Table 2 shows that in the moisture content of the soil the differences between treatments are of small proportions. With green manure crops the moisture requirements for transpiration are high. At the same time they reduce run-off and by shading the soil cut down direct evaporation.

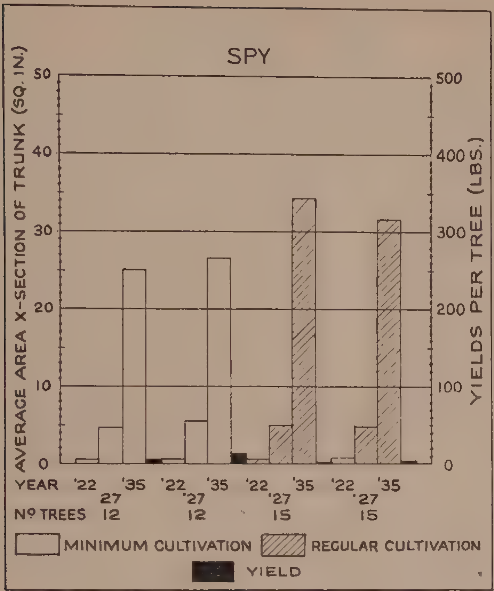

FIGURE 2. See opposite page

Thus while green manure crops consume moisture they also conserve it. Under normal conditions these effects tend to balance one another and probably explain the small average moisture differences between treatments.

Later work in 1936 on soil nitrates conducted by F. B. Strong of the O.A.C., Guelph, suggests that this lack of colour in the foliage and increased fruit colour particularly in the filler varieties, Duchess and Wealthy, may be the result of a nitrate rather than a moisture deficiency. Figure 1 shows a considerable difference in the amount of nitrates in the soil

TABLE 2.—AVERAGE PERCENTAGE MOISTURE (ON DRY WEIGHT) FROM WEEKLY DETERMINATIONS (17 WEEKS)

——	Depth of Soil	1931	1932	1933	1934	1935	Grand average
	inches	%	%	%	%	%	%
Minimum cultivation	0– 6	13.5	16.7	13.5	11.5	11.0	13.2
	6–12	12.7	15.1	12.7	11.3	10.0	12.4
	12–18	12.8	15.5	12.7	10.6	10.0	12.3
Regular cultivation	0– 6	14.4	13.2	13.2	11.7	10.5	12.6
	6–12	13.4	14.6	12.0	12.0	9.5	12.3
	12–18	13.2	15.3	12.0	10.9	9.2	12.1

under the two treatments. Moisture was much as for the former years, 1936 averages being:

Depth of soil in inches	Percentage of moisture, minimum cultivation	Percentage of moisture, Regular cultivation
0– 6	9.2	10.0
6–12	9.6	10.1
12–18	9.0	9.0

The differences in organic matter in 1936 were small and in all cases the amounts were considerably below the amount required for best growth conditions.

Percentage organic matter at three depths (Chromic Acid Method):

——	0–6 inches	6–12 inches	12–18 inches
Minimum cultivation	1.88	0.91	0.64
Regular cultivation	1.93	.75	.51

Growth and Yield

As the filler trees had to be removed in the fall of 1935 one stage of the orchard's development is now completed. This then is a preliminary report on growth and yield for that period of the orchard and is illustrated in the accompanying graph and table (Figure 2 and Table 3). These show the marked uniformity of the trees as measured 1922, the relatively even growth maintained under uniform treatment until 1927 and on the whole the rather small differences in the fall of 1935. The yields except for McIntosh and to a slight degree for Baldwin, show some increase for minimum cultivation.

TABLE 3.—COMPARISON OF SIZE AND YIELD OF TREES UNDER MINIMUM AND REGULAR CULTIVATION TREATMENTS

Variety	Minimum cultivation		Regular cultivation		Gains in favour of Regular cultivation	
	Average area of x-section of trunk (sq. ins.) Nov. 1935	Average total yield (lbs.) 1928–1935	Average area of x-section of trunk (sq. ins.) Nov. 1935	Average total yield (lbs.) 1928–1935	Average area x-section (sq. ins.)	Average total yield (lbs.)
Baldwin	40.7	86.4	46.0	102.9	+5.3	+16.5
McIntosh	46.3	287.3	41.4	327.3	−4.9	+40
Spy	25.9	10.2	33.1	2.4	+7.2	− 7.8
Duchess	22.9	340.8	24.9	323.8	+2.0	−17.0
Wealthy	30.7	256.4	32.4	226.7	+1.7	−29.7

CONCLUSIONS

The differences between treatments have been slight. Duchess, Spy and Wealthy have produced more fruit under minimum cultivation while Baldwin and McIntosh have borne more fruit under the more orthodox treatment.

Differences in size of tree have been almost opposite to the effect on yield. McIntosh trees are larger under the minimum cultivation treatment. Baldwin, Duchess, Spy and Wealthy trees have made greater trunk growth under the longer cultivation.

In moisture content of the soil the differences between treatments were of small proportions.

Soil nitrates have varied greatly between treatments. The 1936 determinations suggest that when green manure crops are sown early, the limiting factor in this experiment may be nitrates rather than moisture.

ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance of Mr. J. R. van Haarlem for the 1931–35 moisture determinations, of Mr. F. B. Strong for the 1936 nitrate and moisture determinations, of Dr. W. H. Upshall for his suggestions on the preparation of the paper and of the other members of the staff who from time to time have assisted in the gathering of the necessary data.

Résumé

Enquête sur la possibilité de réduire le nombre de façons culturales (binages) dans un verger. G. H. Dickson, Station expérimentale d'horticulture de l'Ontario, Station de Vineland, Ontario.

Les différences dans l'effet des différents traitements ont été peu marquées. Les Duchesse, Spy et Wealthy ont produit plus de fruits lorsque les binages étaient réduits au minimum, tandis que les Baldwin et les McIntosh produisaient plus lorsqu'elles étaient soumises au traitement plus orthodoxe. L'effet exercé sur la taille des arbres a été presque l'opposé de l'effet exercé sur le rendement. Les McIntosh sont plus gros quand le traitement est réduit au minimum. Les Baldwin, Duchesse, Spy et Wealthy font leur plus grand développement du tronc lorsque les binages sont prolongés. En ce qui concerne la teneur en humidité du sol, les différences entreles traitements étaient faibles. La proportion de nitrates du sol a beaucoup varié d'un traitement à l'autre. Les déterminations de 1936 montrent que lorsque les récoltes qui doivent servir d'engrais vert sont semées de bonne heure, le facteur limitatif dans cette expérience peut être les nitrates plutôt que l'humidité.

AMERICAN FOULBROOD STERILIZATION EXPERIMENTS 1931-35[1]

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[Received for publication June 12, 1937]

American foulbrood is an infectious disease of the brood of bees caused by a specific organism known to bacteriologists as *Bacillus larvae* (White). The disease, probably known since Aristotle's time, has for centuries been a menace to beekeeping and is still regarded as the most serious disease with which the beekeeper has to contend. The annual losses caused by American foulbrood cannot be accurately computed because of the cumulative effect which is evident once an area becomes infected. However, without fear of contradiction it may be stated that the annual losses are much greater than usually comprehended.

HISTORICAL DEVELOPMENT

During the early history of the disease, beekeepers, while knowing that disease was present, knew nothing of its nature or treatment; as a result, many apiaries were completely wiped out. As losses increased experiments were conducted by a number of beekeepers in an attempt to devise methods of combating the disease. Shirach (7) in 1771 recommended the removal of all combs, starving the bees for two days and giving them fresh combs and feeding the bees a mixture of diluted honey with nutmeg and saffron. Quimby (10) used what he called "the shaking plan", which consisted of shaking the adult bees into a new hive and burning or melting the old combs. This treatment was described before foundation was known, the bees being given empty wooden frames or guides. D. A. Jones (10) of Beeton, Ont. gave out the "Starvation Plan", which was a modified procedure of the combined Shirach and Quimby methods. The bees were shaken into and caged in a wire-cloth box, which was placed in a cool cellar until the bees had consumed all the honey in their honey-sacs. Wm. McEvoy, Inspector of Apiaries for Ontario and N. E. France, Inspector of Apiaries for the State of Wisconsin evolved the "Double-Shake treatment", whereby they removed all the combs, shook the bees back into their original hives, and supplied them with starters of foundation. Four days later the starter combs were removed, burned and replaced with frames containing full sheets of foundation. This method was modified by other beekeepers, who, after the bees had been shaken placed nine frames of foundation and one drawn comb into the hive. The drawn comb was removed 24 hours later and, theoretically, it contained all the regurgitated, infected honey which the bees had taken into their honey-sacs when they were shaken.

Although the bees were saved by shaking them from the infected combs, and the equipment such as hive bodies, supers, covers, and floor boards could be disinfected by scorching, the above methods all required the burning of the infected combs, a loss regarded by many as serious.

[1] Conducted at the Dominion Experimental Stations, Morden and Brandon, Man.
The work described in this article was carried out by the author in co-operation with the Bee Division at Ottawa.

Treatment of the combs with various solutions and gases have been attempted since the early eighties and the reported successes and failures have promoted a good deal of discussion in the beekeeping journals.

The Phenol-cure (9) was tried and recommended in 1884. Water-formalin (3) was used as early as 1890. Dr. H. C. Hutzelman, in 1922, developed, patented and placed on the market a new solution (alcohol-formalin) for the disinfection of combs by immersion. The claims for this solution were numerous, but its use by beekeepers was only partly successful (5). A. P. Sturtevant (12) found that the Hutzelman solution, along with others tested, was unsatisfactory, as used, in that it failed to penetrate the cappings of sealed cells. It was therefore recommended that all cells be uncapped before treatment. E. S. Millar (8), Indiana, and Byer (2), Ontario, found re-occurrence, in thorough field tests, with Hutzelman's solution in 1926 and concluded that the treatment was not only ineffective but that it was a disagreeable task and unprofitable where only a small number of combs were involved, because of the high cost of the alcohol. The alcohol was of no value as a disinfectant and merely acted as a carrier; consequently a cheaper substitute seemed desirable.

In 1923, Prof. H. F. Wilson of Wisconsin, experimented with and reported results with a solution, in which sodium hypochlorite was used, known as "Bacilli Kill".

Water-formalin and soap (13); water, glycerine and formalin (11) were tried with varied results. The success of an immersion treatment of diseased combs seemed to be in the ability of the solution to penetrate into the cells and openings of the comb (4). It has been known since 1906 that formaldehyde is a very staisfactory disinfectant when it comes in contact with the spores of American foulbrood (14). The above mentioned solutions were tested with the idea that a solution, having a low surface tension would penetrate more readily into the cells than a solution having a high surface tension. The surface tension as given by Gilbert (4) for alcohol-formalin is 29.91 and for water-formalin 53.57 dynes per centimeter at 20° C. Soap lowers the surface tension of water but the use of soap, in a heavy concentration, caused the wax of the combs to be broken down. When the solutions were diluted considerably, it was found that the surface tension was not reduced.

In 1928, Jarvis (6), after conducting four years experiments with immersion treatments arrived at the following conclusions:—

1. "That alcohol-formalin and water-formalin do not always give 100% efficiency where massed spores are concerned."

2. "That the treating of brood combs may mean the harbouring of disease or even cause it to spread from lack of proper storage facilities."

The above conclusions were based upon field tests in which package bees were placed upon treated combs.

Gases of various kinds, used in closed chambers or otherwise, were experimented with for many years with discouraging results (5).

In the Prairie Provinces the disease inspection forces, with the help of rigid inspection laws, had more or less convinced the majority of beekeepers that "Cyanogas, the pit and fire" was the most efficient method of eradicating American foulbrood. The chlorine treatment, developed

and advocated by H. G. Ahrens and Dr. M. C. Tanquary (1), in 1932, was received with a great deal of enthusiasm by the anti-fire group, because, if effective, it meant that infected combs could be treated cheaply and saved. Numerous beekeepers in the United States and Canada immediately took steps to try out this new method. Dr. Tanquary, in the fall of 1932, compiled a report from a questionnaire on the results of this treatment in the various States and Provinces, but in so far as the writer is aware, this report has not yet been published.

A bulletin (1933) on the treatment of American foulbrood, published by the U.S. Dept. of Agriculture, advised the killing of the bees and burning of the entire contents of the hive as the only treatment to be recommended; This advice endorses the policy of our western inspectors.

For the purpose of proving or disproving the claims of the various adherents to the theory of treating infected combs with chemicals and to test the efficiency of the various solutions that are now being recommended for the sterilization of brood and super combs, a project was begun at the Dominion Experimental Station, Morden, Manitoba in the summer of 1931.

The following is a brief progress report of results obtained to date (Oct. 1935). Lack of space prevents inclusion of detailed yearly results, consequently representative material is chosen to illustrate the type of data accumulated.

PROCEDURE

A. An out-apiary of six healthy colonies, known as Apiary No. 1 was established, July 30, 1931, in a district where no bees were kept within a radius of at least three miles. These colonies were purposely infected with American foulbrood as indicated in Table 1, and after infection were examined once each week to note the rate at which the disease spread in each colony. Ample supers of foundation were supplied for the storage of honey and every care and caution was observed to keep the colonies from swarming. The bees in all colonies were destroyed with Cyanogas as soon as the honeyflow was over, placed in a hole in the ground and deeply covered with dirt. All of the equipment, such as, broodchambers and supers, together with the combs they contained, floorboards, covers, queen excluders and hive stands, were stored in a bee-tight building for treatment.

In the spring of the following year, all the equipment, with the exception of the combs, was thoroughly scraped and flamed over with a blow torch. The infected brood and super combs were uncapped, the honey extracted and the combs suspended in water, the latter being changed daily, to remove all of the honey which had remained in them. After the honey had been removed, the combs were divided into groups and treated as follows:—

1. Water-formalin (80 parts water and 20 parts formalin).
2. Alcohol-formalin (40 parts water—40 parts alcohol—20 parts formalin).
3. Chlorine gas in water (as outlined in paper No. 255 Univ. of Minn.).
4. Water (Super combs only).

Sample pieces of comb (two inches square), containing scales if possible, were taken from each group of combs before being treated and again after

TABLE 1.—APIARY NO. 1—INOCULATION OF HEALTHY COLONIES

1931

Colony number	Type of inoculant used, scale-liquid or frames with affected cells and honey	Date inoculated	Method used in inoculating	Strength of colony at inoculation date	Date infection first noticed	Rate of spread	Distribution from infection loci	Remarks	Date de-queened	Yield
				Bees–Brood–Eggs						
30	Infected honey with two liquid cells in 50 cc. of water.	Aug. 4	Poured over combs	6–1–0	Sept. 13	V. slow		Infected honey containing two liquid cells given Aug. 24.	Sept. 3	0.0
34	Eight liquid cells in 100 cc. of water.	Aug. 4	Poured over combs	20–4–3	Aug. 24	Slow	One cell inoculated frame 4 on adjoining frame.		Sept. 3	45.0
44	Four scales in 50 cc. of water.	Aug. 4	Poured over combs	40–7–3	Sept. 13	Slow		Infected honey containing two liquid cells given Aug. 24.	Sept. 3	208.5
47	Eight scales	Aug. 4	Inserting piece of infected comb.	30–5–3	Aug. 24	Rapid	General distribution where larvae were hatching.	Aug. 8 scale piece chewed to base of foundation and rebuilt.	Sept. 3	181.5
57	Eight scales.	Aug. 4	Inserting piece of infected comb.	30–5–3	Aug. 24	Rapid	General distribution where larvae were hatching.	Aug. 8 scale piece chewed out entirely, no evidence of its presence.	Sept. 3	201.0
76	Infected in homeyard. (3 cells).		Bees brought it, source unknown.	20–6–3	July 24	Rapid	General.		Sept. 3	275.0

TABLE 1.—APIARY NO. 1—INOCULATION OF HEALTHY COLONIES—*Concluded*

1932

Colony number	Type of inoculant used, scale-liquid or frames with affected cells and honey	Date inoculated	Method used in inoculating	Strength of colony at inoculation date	Date infection first noticed	Rate of spread	Distribution from infection loci	Remarks	Date de-queened	Yield
				Bees–Brood–Eggs						
66	One fr. numerous scales, no honey.	May 28	Placed in centre of the broodnest.	7–$2\frac{1}{2}$–$1\frac{1}{2}$	June 11	Rapid	Six side, combs—June 18, three queencells, many drone cells Sept. 1.	Dead queen pupae—negative.	Sept. 12	60.0
74	One fr. numerous scales, no honey.	May 28	Placed in centre of the broodnest.	5–1–1	June 11	Rapid	Five side combs and starter—June 18, five queen cells Sept. 1.	Dead queen larvae-positive.	Sept. 12	20.0
91	One fr. numerous scales, no honey.	May 28	Placed in centre of the broodnest.	6–3–2	June 11	V. rapid	Six combs on sides—June 18.	Dead queen pupae and drone larvae-positive.	Sept. 12	55.0
98	One fr. numerous scales, no honey.	May 28	Placed in centre of the broodnest.	8–2–1	June 11	V. rapid	Six combs and starter—June 18.		Sept. 12	95.0
109	One fr. numerous scales, no honey.	May 28	Placed in centre of the broodnest.	5–3–1	June 11	Rapid	Two combs on sides—June 18.	Virgin reared and mated; eggs from C98, eight queen cells, three positive.	Sept. 12	65.0
110	One fr. numerous scales, no honey.	May 28	Placed in centre of the broodnest.	8–3–3	June 11	Extra rapid	Seven combs on sides—June 18.	Tried to supersede queen July 18.	Setp. 12	67.0

1935

1 (7)	One fr. numerous scales, no honey.	June 21	Placed in the centre of the broodnest.	17–5–5	July 3	Very rapid	Four side combs in lower rbroodchamber July 12. three frames in 2nd broodchamber.	Cultural tests on samples of July 3—positive; Aug. 31, worker, drone, queen, larvae and pupae —positive.	Aug. 20 116.0
2 (10)	One fr. numerous scales, no honey.	June 21	Placed in the centre of the broodnest.	12–4–3	July 12	Rapid	Four side combs and starter; two cells in 2nd broodchamber, July 12	Aug. 31 worker, drone and queen pupae-positive.	Aug. 20 100.0
3 (11)	One fr. numerous scales, no honey.	June 21	Placed in the centre of the broodnest.	10–5–2	July 3	Very rapid	Eight side combs and starter in lower broodchamber July 12.	Diagnosis of five cells July 3—positive; Aug. 31, worker, drone, larvae and pupae, queen larvae and pupae—positive.	Aug. 20 68.5
4 (13)	One fr. numerous scales, no honey.	June 21	Placed in the centre of the broodnest.	11–3–3	July 3	Very rapid	Eight side combs and starter in lower broodchamber.	Diagnosis of cells July 3 positive—Aug. 31; worker, drone, scale and queen larvae—positive.	Aug. 20 32.5
5 (14)	One fr. numerous scales, no honey.	June 21	Placed in the centre of the broodnest.	18–5–2	July 3	Rapid	Five side combs and starter in lower broodchamber; one fr. in 2nd broodchamber July 12.	Diagnosis of cells July 3 —positive; Aug. 31, worker, drone, scale and pupae, queen larvae and pupae positive.	Aug. 20 67.0
6 (18)	One fr. numerous scales, no honey.	June 21	Placed in the centre of the broodnest.	11–3–3	July 3	Very rapid	Eight side combs and starter in lower broodchamber; three frs. in 2nd broodchamber July 12.	Diagnosis of cells July 3 — positive; Aug. 31 worker, drone, scale and larvae, queen larvae positive.	Aug. 20 65.5

treatment. These samples were forwarded to the Dominion Agricultural Bacteriologist, Ottawa, for cultural purposes, to ascertain the disinfecting effects of the various solutions used.

B. Package bees were hived on the treated material which had been taken to Apiary No. 2, located at least $1\frac{1}{2}$ miles, as the bee flies, from Apiary No. 1 and they were fed sugar syrup until nectar was coming in freely from the fields.

Three, 2-pound, and three 3-pound packages were hived on May 13, 1932. Two packages were hived on water-formalin, two on alcohol-formalin, and two on chlorine treated combs. In 1933, and each succeeding year thereafter, twelve 2-pound packages were used, four on each group of treated combs.

Individual sets of coveralls, smoker, hive tool, etc., were provided at each outyard and the operator examined Apiary No. 2 before proceeding to Apiary No. 1. All the necessary precautions regarding disinfecting etc., were taken at Apiary No. 2 when re-occurrence of the disease was observed to prevent infection of other colonies in this apiary. Any colony showing re-occurrence of the disease was promptly removed from Apiary No. 2 to Apiary No. 1.

INOCULATION RESULTS ON HEALTHY COLONIES

Apiary No. 1. The results obtained in colonies 30, 34, and 44 (Table 1) 1931 show that the concentration of the inoculant used in colonies 30 and 44 was too low to provide a rapid development of the disease. As the date of inoculation was late in the season and the express purpose of inoculating was the provision of material for subsequent treatment, these two colonies were therefore given a small quantity of honey into which had been stirred the liquid contents of two cells of diseased material, on August 24. Colonies 47 and 57, into which a small piece of comb (1 inch × 1 inch), containing 8 scales, had been inserted, provided a fairly rapid infection; the interesting point in this connection is that in colony 47 the bees had chewed the cells of the inserted piece down to the base of the foundation and rebuilt them. In the latter the scale-containing piece had been entirely eaten out. No evidence of its presence could be found either on the floor board or in front of the hive; thus it was concluded that the bees had chewed it down completely. The yields of the inoculated colonies are given, not for comparative purposes of individual colonies, but to indicate relative trends which might possibly show the difference between early and late infection of colonies on the honey crop (the strength of colony considered), for the two years 1931–32).

In 1932 and subsequent years the type of inoculant and the method of inoculation was identical in all colonies. The time factor, from date of inoculation until disease was first noticed, was 20, 14, 16 and 12 days in 1931, 1932, 1934 and 1935 respectively. The rapidity of the spread of the disease in 1932 was sharply contrasted with that of the previous year. The distribution from the infection loci was of much interest. In all 24 colonies the signs of the disease were first noticed in the combs on either side of the "inoculation comb". In the majority of the colonies it was readily apparent that the queens passed from one side of the broodchamber to the other, forming a symmetrical broodnest but ignoring the "starter or

inoculation comb" in the centre of the brood nest. When frames of foundation were supplied in the second broodchamber, the queens preferred to lay their eggs in partially constructed combs rather than in old brood comb partially or heavily infected with American Foulbrood.

Signs of general weakening in a colony, as a direct result of the disease, depend upon the strength of the colony at inoculation date; the time of inoculating, viz:—early spring, early or late summer; and the rapidity of the spread within the hive. However, on the average, a general weakening in colony strength is readily noticeable from 4–6 weeks after inoculation. One very important feature of the project was the discovery of dead queen larvae, pupae and drone larvae, and pupae that gave positive cultural tests of the disease, thus bearing out White's and Sturtevant's contentions that the disease is not limited to worker larvae alone but is also found in queen and drone larvae. To the writer's knowledge this is the first reported case of a queen and drone pupae showing positive cultural tests for American Foulbrood.

Several virgin queens were reared in heavily infected colonies. They became mated in due time and laid regularly until they were killed at the end of the season. The colonies in Apiary No. 1 were dequeened in the fall of each year to allow all healthy brood to emerge so that no additional complications would enter into the treatment of the combs the following year.

The average production for the 24 colonies inoculated was 93.16 pounds.

RESULTS ON THE METHODS OF TREATMENT

Apiary No. 2. In the spring of the year, following inoculation, the combs from Apiary No. 1. were treated as illustrated in Table 2.

TABLE 2.—APIARY NO. 2—METHODS OF TREATMENT
1934

No. of combs treated	Description—brood or super comb	Solution used for treating	Percent of formalin in solution	Date treatment began	Outside max. and min. temperature during treatment	Length of time in solution (in hours)	Length of time exposed to air before given to bees	No. of combs broken by June 15
20	Brood	Water-formalin	6.12	Apr. 20	60.7–26.5	48	8 days	1
20	Brood	Alcohol-formalin	7.47	Apr. 20	60.7–26.5	48	8 days	2
20	Brood	Water-formalin	6.12	Apr. 22	60.2–30.5	48	6 days	0
20	Brood	Alcohol-formalin	7.47	Apr. 22	60.2–30.5	48	6 days	2
20	Brood	Water-formalin	6.12	Apr. 24	58.5–23.5	48	40 days	0
20	Brood	Alcohol-formalin	7.47	Apr. 24	58.5–23.5	48	40 days	0
40	Brood	Chlorine	—	Apr. 30	52.0–31.0	Gas on 51 hrs. Gas off 18 hrs.	3 days	25

N.B.—Solutions containing formalin were those used the previous two years, and had been exposed to −36 degrees below zero weather. Additional alcohol and formalin were added from time to time to keep the solutions up to strength and to cover the combs in the treating tanks.

The brood combs, only, were treated in 1932 whereas both brood and super combs were treated in subsequent years. The length of time the combs were aired before given to the bees varied, depending upon the

availability of the chlorine gas and suitability of weather conditions to perform the work.

The chlorine treatment was continued for a longer period, each season, than advised by Ahrens and Tanquary (1). This additional time was given to provide a greater margin of safety and to prevent undue criticism of a factor which might possibly be of the greatest importance in the success or failure of the experiment.

The effect of the treatments on the combs, disregarding those factors which effect the wax and only including the practical manipulation of the combs, indicates that the value of the combs is not seriously impaired by the use of water- or alcohol-formalin but that chlorine due to its corrosive action on the wires impairs the value of the combs very materially. It is not to be presumed that many of the broken combs, listed in the table, had to be discarded but that these combs required additional attention, either before or after the bees had clustered on them. Repairing the combs, by refastening the wax, fitting in foundation where pieces of comb had been broken, and replacing corroded wires, depreciates the value and materially increase the cost of treatment. These results are in direct contradiction to Ahrens (1) statement that "The effect (of Chlorine) on foundation wire and metal hive parts is so slight that it may be disregarded."

The combs treated with water-formalin and alcohol-formalin gave off sufficient formalin odour, after being aired, to make manipulation disagreeable.

The chlorine odour, from the treated combs, was sufficiently strong, after being aired for five days, to give the manipulator the effect of a severe cold. This treatment, therefore, should not be conducted in a closed room or building, neither should the treated combs be stored where it may be necessary for humans to stay or work for any length of time. The wax, in the chlorine group became extremely brittle and white (bleached) in colour. Care must be exercised to reduce the amount of manipulation of such combs to a minimum until the brittleness has disappeared and the natural color of the combs restored.

THE COST OF TREATING COMBS AND PURCHASING NEW EQUIPMENT

The following is a detailed statement of the costs involved in treating combs as compared to new equipment for the year 1935. In the water- and alcohol-formalin treatments the solutions are retained after treatment and stored, then by the addition of the various constituents, brought to proper strength for treating combs the next spring. The original cost has been calculated in the four-year average and these figures should be used for comparative purposes.

It is not to be assumed that the figures in Table 3 can be taken as a standard and applied to the cost of treating combs in large quantities. They do, however, give a relative measure of comparison, indicating that the treatment of a small number of combs is not a profitable venture. The cost of the chlorine treatment remains fairly constant. The original cost of the water- and alcohol-formalin per comb amounted to 0.286 and 0.810 cents, respectively in 1932. This cost was materially reduced in 1935 due to the continued use of the water- and alcohol-formalin solution

TABLE 3.—COST OF TREATING COMBS
1935

CHLORINE

Number of combs treated (40)			
Uncapping and placing in water tank	4 hrs.	@ 30¢	1.20
Changing water	1 hr.	@ 30¢	.30
Setting up equipment	1 hr.	@ 30¢	.30
Looking after set up	1 hr.	@ 30¢	.30
Shaking solution out of combs	1 hr.	@ 30¢	.30
Refastening combs with broken wire	1 hr.	@ 30¢	.30
Cost of Chlorine	10 lbs.	@ 16¢ per lb.	1.60
Freight on Chlorine to and from Toronto, Ont.			3.77
Scorching supers, bottom boards and covers	2 hrs.	@ 30¢	.60
Total cost			8.67
Cost per comb			.217
Combs broken or wire eaten through		6	
Combs or wires broken after packages installed		0	
Total		6 or 15%	

ALCOHOL-FORMALIN

Number of combs treated (80)			
Uncapping and placing in water tank	8 hrs.	@ 30¢	2.40
Changing water	1 hr.	@ 30¢	.30
Setting up equipment	½ hr.	@ 30¢	.15
Shaking solution out of combs and checking for capped cells	1½ hrs.	@ 30¢	.45
Cost of alcohol added to last year's solution	1½ gal.	@ 81¢	1.21
Cost of Formalin added to last year's solution	½ gal.	@ 1.85	.92
Scorching supers, bottom boards and covers	3 hrs.	@ 30¢	.90
Total cost			6.33
Cost per comb			.079
Average cost per comb for a 4 yr. period			.169

Last year's solution, after freezing, tested 7.23% formaldehyde.
No. of combs broken—1.

WATER-FORMALIN

Number of combs treated (80)			
Uncapping and placing in water tank	8 hrs.	@ 30¢	2.40
Changing water	1 hr.	@ 30¢	.30
Setting up equipment	½ hr.	@ 30¢	.15
Shaking solution out of combs and checking for capped cells	1½ hrs.	@ 30¢	.45
Cost of Formalin added to last year's solution	2 gal.	@ 1.85	3.70
Scorching supers, etc.	3 hrs.	@ 30¢	.90
Total cost			7.90
Cost per comb			.099
Average cost per comb for a 4 yr. period			.138

Last year's solution, after freezing, tested 6.99% formaldehyde.
No. of combs broken—3.

COST OF NEW EQUIPMENT

50 Hoffman self spacing frames (K.D.)			1.80
¼ lb. No. 28 frame wire			.19
Nailing 50 frames	½ hr.	@ 30¢	.15
Wiring 50 frames	2 hrs.	@ 30¢	.60
7 lbs. of foundation		@ 45¢ per lb.	3.15
Total Cost			5.89
Cost per frame			118

as mentioned previously. The water-formalin solution from the standpoint of cost, would be the most favorable, providing it could be proven 100% efficient. However, the cost of new equipment so closely approximates even the lowest cost for treating that it would seem inadvisable to recommend treating the combs by any of the methods mentioned in this article.

FIELD TESTS

The field tests were conducted with two colonies, in each of the following methods: water-formalin, alcohol-formalin, and chlorine in 1932; this was increased to four colonies in each of the methods for all subsequent years of the experiment. The field results for 1933 are shown in Table 4.

Fanning by bees, after hiving, was observed in all methods of treatment. The odour of the formalin, in the water- and alcohol-formalin groups, sometimes disappeared rapidly and in other cases persisted until late in July depending upon the length of time the combs were aired, the rapidity with which the colony built up in the spring and general weather conditions. The odour of chlorine was more intense and remained in the hives from two to three weeks longer than in the other groups. The bees in the chlorine group clustered close to the entrance and frequently migrated into the empty feed super to escape the odour from the combs. Furthermore, certain areas of comb were shunned by the bees until the colonies were built up to fair strength.

Considerable drifting of bees occurred, after hiving on treated combs, but this cannot be attributed to normal factors because these packages were hived in a similar manner to those in the homeyard where no drifting occurred. The odour of the treated combs, mentioned above, may be an important factor in this regard.

The brood was decidedly patchy in all three methods but no definite conclusion could be drawn as to the reason for this result. It was observed that wherever new pieces of comb were constructed in frames containing broken comb the queens preferred to lay their eggs in the new comb instead of the available treated comb. An abnormal annual depletion of colony population was apparent after the package bees had been hived on the treated combs. In 1935 this loss practically annihilated some of the colonies before sufficient young bees could be reared to maintain the colony strength.

Chemical determinations showed from 0.017 to 0.062% of formaldehyde present in the dead bees and brood submitted for analysis. In pollen masses cut from the comb of the water- and alcohol-formalin treated combs, 0.012 and 0.033% of formaldehyde was present, respectively. Some of the dead bees separated from the combs and examined individually showed formaldehyde to be present to the extent of 0.0000024 grams per bee. Samples of bees, writhing in agony, collected June 7, from two colonies showed 0.000004 and 0.000006 grams of formaldehyde per bee, respectively. No authoritative data were available on the toxicity of formaldehyde to insects, so it can only be presumed that the large percentage of annual loss of bees on water- and alcohol-formalin treated combs was due to formaldehyde poisoning. Whether death of the bees was due to formaldehyde deposits in the empty cells or from formaldehyde ingested with treated pollen masses is an open question which requires additional

TABLE 4.—FIELD RESULTS FOR 1933

No. of colony	Treatment of brood combs	Treatment of combs in second brood chamber and super	Bacteriological analysis of samples of brood combs after treatment (Ottawa)	Re-occurrence of A.F.B. Date observed	Bacteriological analysis	Yield, in lbs.	Remarks
8	Water-formalin	Water	4—Negative			35.0	July 31, queen right centre leg paralyzed and died May 20.
9	Water-formalin	Foundation	4—Negative	Aug. 15	Positive	30.0	New package, June 5.
10	Water-formalin	Water-formalin	4—Negative			25.0	Cluster dead May 20, new package June 5.
11	Water-formalin	Foundation	3—Negative 1—Positive	July 31	Negative	110.0	
12	Alcohol-formalin	Water	4—Negative	Aug. 22	Positive	45.0	Superseded queen May 20; 2* bees added June 5.
13	Alcohol-formalin	Foundation	4—Negative			65.0	
14	Alcohol-formalin	Water-formalin	4—Negative			55.0	
15	Alcohol-formalin	Foundation	4—Negative			25.0	Queen lost on intro. May 6; virgin no good; laying queen intro. June 5.
16	Chlorine	Foundation	4—Negative	July 3	Positive	80.0	
17	Chlorine	Foundation	4—Negative			50.0	2* bees added June 5.
18	Chlorine	Water-formalin	4—Negative	May 30	Negative	65.0	
19	Chlorine	None used	4—Negative			30.0	2* bees added June 5; queen both hind legs paralyzed June 10. Requeened July 14, centre leg paralyzed after intro.
		Total production				615.0	
		Average production				51.2	

research work. The possibility of re-occurrence of the disease was carefully checked in each colony at every examination. Microscopic diagnoses of suspicious looking larvae were verified by submitting a sample to the Bacteriological Division, Ottawa, for cultural purposes. The re-occurrence of American Foulbrood on treated comb was as follows: in 1932 two colonies on chlorine treated combs; 1933, one colony on water-formalin, one on alcohol-formalin treated comb (the re-occurrence in this colony may have been due to the use of a super full of water-treated combs as a second broodchamber), and one colony on chlorine treated combs; in 1935, four colonies on chlorine treated combs.

The yield results are given in Table 4 merely to indicate the possibility of the effect that treated combs may have on package bees, operated commercially. The production of 42 packages hived on treated combs was 35.2 pounds on the average. The average yield for packages hived on untreated combs, and received between April 29 until June 5, in this district, was 113.9 pounds over a 10-year period.

Colonies surviving at the end of the season, showing no re-occurrence of the disease and being sufficiently strong in bees, were packed in two-colony balsam-wool packs and wintered-over. Those colonies surviving the winter were carefully checked for re-occurrence of the disease the following year. None of the over-wintered colonies showed any signs of the re-occurrence of American Foulbrood. Table 5 briefly outlines the data recorded.

TABLE 5.—TREATED COLONIES OVER-WINTERED, 1933–34

Colony No.	Combs—how treated	Did colony swarm—date	How treated	Was colony requeened—date	Yield	Remarks
7	Water-formalin 1932	July 14 July 23	Returned.	Virgin-mated Aug. 2	99.00	Shook 2* package June 18, 2 suspicious cells July 14 no further sign during season.
10	Water-formalin 1933.	—	—	—	116.00	Built up slowly.
11	Water-formalin 1933			Superseded July 14	99.00	Shook 2* package June 18
13	Alcohol-formalin 1933	—	—	Superseded July 14. Aug. 30 killed 2nd virgin, introduced laying queen.	97.00	
14	Alcohol-formalin 1933	July 14	Swarm lost	Raised own queen	101.00	Robber in spring, two cells suspicious of A.F. B., May 26, bacteriological cultures negative, no further sign of disease.
18	Chlorine 1933	Preparations for July 14. Divided Aug. 2	Demareed	Superseded Aug. 15.	145.00	Robber in spring.
	Total				657.00	
	Average				109.50	

SUMMARY

1. Inoculation of healthy colonies with infected food or combs provides a definite infection loci in twelve days.

2. Infection within a colony may not be evident on the comb containing the primary source of infection until the disease has been thoroughly disseminated through the hive.

3. Queen and drone, larvae and pupae, were found to be infected with American Foulbrood. Thus a queen or drone cell may harbour the disease as well as worker cells. Therefore queen and drone cells should be carefully inspected and queen cells should not be cut from an infected colony and transferred to a healthy colony because this practice may result in the spread of the disease from one apiary to another.

4. Colonies with a light infection may not show any apparent weakening and produce a good crop, but will be an immediate source of further infection during the autumn or early spring.

5. Robbing, the laissez-faire policy in regard to weak colonies in the fall and spring, the unsatisfactory storing of diseased equipment, the interchanging of brood combs without adequate inspection of the colonies and the exchanging of beekeeping equipment among beekeepers are the most common means for the dissemination of the disease.

6. The cost of new equipment, per comb, is lower than the cost of treating (on small scale operations), based on the initial cost, in all three methods.

7. The percentage of broken combs and the difficulties encountered during the manipulation of such combs materially increases operating costs. The chlorine treatment from this standpoint would be less desirous than the water- or alcohol-formalin treatments.

8. The use of forma in or chlorine entails certain hazards to the health of the operator, which in some cases may have lasting effects consequently the effect on bees of the odours of treated combs, although problematical, is a factor that should be taken into consideration. Excessive fanning of the bees for an extended period when placed on such combs indicates that the chlorine odour is more penetrating and adheres for a longer time than that of formalin. The effect of paraformaldehyde formation, or ingestion of formaldehyde in pollen masses, may have been a contributing factor to the rapid depletion of colony population in early spring.

9. The water-formalin and chlorine treatments, in a 4-year trial, cannot be regarded as 100% efficient under ideal experimental conditions. The efficiency of the alcohol-formalin treatment is still in doubt. (It would be well, however, to note that careful investigators in the United States, namely Dr. A. P. Sturtevant and C. H. Gilbert, in well planned experiments, obtained re-occurrence with this last mentioned solution.)

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Résumé

Essais de stérilisation contre la loque américaine, 1931-35. Erdman Braun, station expérimentale fédérale, Brandon, Manitoba.

L'inoculation de ruches saines avec des aliments ou des rayons infectés produit en douze jours un foyer bien net d'infection. Cependant, l'infection peut ne pas être visible sur le rayon contenant la source primaire de l'infection tant que la maladie n'est pas complètement répandue dans la ruche. Dans certains cas, la reine et les faux bourdons, les larves et le couvain, étaient infectés de la loque américaine. Ceci montre qu'une cellule de reine ou de faux bourdon peut loger la maladie tout aussi bien que les cellules d'ouvrières. Il faut donc inspecter soigneusement les cellules royales et de faux bourdons et ne jamais enlever les cellules royales d'une ruche infectée pour les transférer à une colonie saine parce que cette pratique peut propager la maladie d'un rucher à l'autre. Il est possible que les colonies légèrement infectées ne révèlent pas d'affaiblissement apparent et produisent une bonne récolte, mais elles constituent une source immédiate d'infection pendant l'automne et au commencement du printemps. Le pillage, le régime de laissez-faire en ce qui concerne les colonies faibles en automne et au printemps, la conservation de fournitures ou de matériel portant des germes de maladie, l'échange de rayons de couvain sans qu'une inspection adéquate soit faite des ruches, et l'échange de matériel apicole parmi les apiculteurs, sont les agents de dissémination les plus communs. Le coût du matériel neuf, par rayon, est moins élevé que le coût du traitement (sur des opérations de petite envergure), basé sur le coût initial dans chacune des trois méthodes. Le pourcentage de rayons brisés et les difficultés que l'on éprouve dans la manipulation de ces rayons, augmentent beaucoup les frais d'exploitation. A ce point de vue, le traitement au

chlore serait moins avantageux que le traitement à l'eau ou à la solution alcool-formaline. L'emploi de formaline ou de chlore entraîne certains risques pour la santé de l'exploitant, qui peuvent même, dans certains cas, avoir des effets durables. Par conséquent, l'effet sur les abeilles de l'odeur des rayons traités, quoique problématique, est aussi un facteur dont il convient de tenir compte. La ventilation excessive et prolongée, pratiquée par les abeilles placées sur ces rayons, indique que l'odeur de chlore est plus pénétrante et qu'elle adhère plus longtemps que celle de la formaline. L'effet de la formation de paraformaldéhyde, ou l'ingestion de formaldéhyde dans les masses du pollen, peut avoir été l'un des facteurs principaux de la diminution rapide de la population de la ruche au commencement du printemps. Les traitements d'eau et de formaline et de chlore, dans un essai de quatre ans, ne peuvent être considérés comme complètement efficaces dans des conditions idéales d'expérimentation. L'efficacité du traitement alcool-formaline est encore en doute. (Il est bon de noter que des chercheurs consciencieux aux Etats-Unis, les docteurs A. P. Sturtevant et C. H. Gilbert, ont obtenu, dans des expériences bien conçues, une réapparition de la maladie lorsque cette dernière solution était employée.)

THE PEA MOTH, *LASPEYRESIA NIGRICANA* STEPH., ON THE GASPE COAST

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The main pea growing areas on the Gaspe coast are situated between Chandler and Percé. These regions all lie within the county of Gaspe. Starting in 1934, commercial growing of Tall Telephone peas became general in the districts of Hope Town, St. Godfroi, and Shigawake, with more thinly scattered plots being sown in New Carlisle, New Richmond, and St. Charles Caplan. All these latter places are situated in the county of Bonaventure. Thus Gaspe county contains the older and considerably larger pea growing areas as compared with Bonaventure county.

For the sake of brevity, all references in this report to the pea growing areas of the "St. Godfroi district" will include the areas covered by Hope Town, St. Godfroi, and Shigawake, unless stated otherwise.

In 1934, a total of 750 pounds of pea seed was sown in the St. Godfroi district. From this sowing shipments of 2,928 baskets of peas were made from St. Godfroi. In 1935 the pea areas were considerably increased and 2,300 pounds of seed were sown, representing an increase of over 300 per cent of that sown the previous year. The yield, however, was slightly lower than that obtained in 1934. Shipments totalled 2,889 baskets in 1935. Pea moth injury was severe in both 1934 and 1935 but in the latter year it was found necessary to discontinue marketing of peas by August 15 when the last shipment was made from St. Godfroi for that year.

The losses experienced from pea moth were so severe in 1934 and 1935 that they resulted in a drastic reduction in the area sown to peas in the St. Godfroi district in 1936. In this year only 520 pounds of pea seed were sown, the lowest amount since pea-growing started in St. Godfroi and representing only about one-fifth of that sown in 1935. In 1936 the shipments of peas fell off to a total of 996 baskets for the year.

The total shipments of green peas from the Gaspe peninsula for the past three years, were for 1934—25,868 baskets, 1935—18,474 baskets, and for 1936—21,884 baskets.

Agricultural Practices and Climatic Conditions

There is a wide variation in agricultural practice in relation to pea growing on the Gaspe coast. Peas are usually sown in double rows placed about four feet apart. In many cases the distance is reduced to three feet or even less. After the plants are well out of the ground they are staked. For this purpose young conifers are widely used. The bases of these trees are pointed and driven into the ground to furnish support for the double line of plants in a row. These "stakes" are carried over from one year to another and probably last four or five years. Where conifers are not available young birch trees or branches are used for staking the peas. There are several different systems of arranging the stakes. Seaweed is used quite extensively as a fertilizer, particularly along the shore ranges.

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Climatic conditions along the Gaspe vary to quite a marked degree. In general, the seasons are earlier as one gets further up the Bay of Chaleur. Thus the main pea growing areas of Percé, Cape Cove, and Grand River, have a growing season that is usually ten days or two weeks later than that of the St. Godfroi pea growing areas of Bonaventure county. The prevailing winds along the coast are chiefly from the southwest and west-southwest. These are usually the fair weather winds, and most of the severe storm winds come from the northeast. The line of sub-division between the different climatic regions referred to above appears to occur near Mackerel Point which is to be found near Newport.

During the growing season of 1936 a weather station was in operation at St. Godfroi. A barograph, hydrograph, anemometer, sunshine recorder, maximum thermometer, minimum thermometer, dry thermometer, wet thermometer, rain gauge and a wind vane were in use at this weather station.

Plant growth is usually rather slow until the middle of June. After the 15th of June, growth is quite rapid.

The season of 1936 was later than usual so that seeding and subsequent growth of the pea plants were considerably retarded. The summer was not characterized by much hot weather and it was only during the second week of July and the first two weeks of August that the average weekly maximum temperatures went over 70° F. Temperatures on the third range at St. Godfroi are normally higher than those on the first range, particularly after dark. The reverse appears to be the case in the autumn of the year. From June 13 until the end of September, 11.62 inches of rain fell in the St. Godfroi district. This was divided as follows: June 13-30, 3.68 inches; July, 3.08 inches; August, 2.90 inches; and September, 1.96 inches. High winds occurred on July 7 and caused some injury to pea vines due to the plants whipping against their supports and becoming bruised or broken. Fog is not as prevalent near St. Godfroi as it is farther down the coast around Cape Cove, etc. Damp weather in July, particularly from the 12th to 14th, probably assisted in the growth of pea blight and pea spot—of which there was a widespread initial infection showing in most fields at this time.

Host Plants of Pea Moth

The pea moth is quite prevalent in garden patches of Tom Thumb peas. Field peas are also infested. The latter appear to have a tendency to flower and mature somewhat later than the Tall Telephone peas. The question of field pea infection will be important in any clean up program that may be adopted. In general, small patches of peas are usually more liable to show infestation than larger plantings. This may be due to there being a certain number of moths emerging in a definite area. If there are only a few peas easily accessible, they will probably be heavily infested. If, on the other hand, the acreage is large, the same number of eggs and worms will be distributed over a greater number of vines and thus show a lighter infestation per plant.

Vetch is present throughout the St. Godfroi district, but pea moth eggs, larvae or adults could not be found on these plants until near the end of the growing season. A few larvae were eventually recovered from vetch

pods which closely resembled the larvae of the pea moth. The vetch came into bloom before the pea plants and continued blooming for most of the season.

Distribution of the Pea Moth on the Gaspe Coast

At the commencement of this investigation the pea moth was known to be present in St. Godfroi. There were no records of the presence of this insect beyond the limits of this small area. Surveys soon showed that it was thoroughly distributed throughout the St. Godfroi district and was present in all four ranges where peas were grown. Scouting outward from the St. Godfroi district the insect was traced as far as New Carlisle to the southwest and to Port Daniel on the northeast. Continuing to work outward, with St. Godfroi as a centre, the pea moth was gradually traced southward along the coast up to the head of the Bay of Chaleur and finally into New Brunswick to Campbellton. How long, it has been present in Gaspe is, of course, difficult to say. Many farmers remember seeing the insect in their field peas frequently for the past twenty or thirty years. Tall Telephone peas were first grown in St. Godfroi in 1934. The character of the pea moth infestation in that and susbequent years indicates the presence of the insect in considerable numbers prior to commercial pea growing. Injury from pea moth was very severe even during the first year of commercial growing of green peas. The widespread distribution of the pea moth and also its presence in inaccessible isolated areas lend additional support to the theory of long residence of the insect on the Gaspe coast.

Tracing the infestation along the coast northward from St. Godfroi finally showed the pea moth to be present in comparative abundance as far as Gascon. For some time thereafter the insect could not be traced beyond this point. From Gascon, through Newport, to Chandler there is an important natural barrier of stony, wooded areas which are unsuitable for any extensive land cultivation. However, later in the season the insect was finally located on the other side of this barrier in and beyond Chandler. This put the insect definitely within Gaspe county and on the southern edge of the main pea growing areas located in Gaspe county.

With knowledge gained as to some of the probable factors influencing the distribution of the pea moth on the Gaspe coast, an intensive search was started for the insect around Gaspe village (110 miles from St. Godfroi). The insect was finally located in Gaspe and St. Marjorique. This placed it north of the main pea growing areas.

In addition to the above infested areas, it was finally possible to show that the pea moth is very thinly distributed around St. Adelaide and also Grand River. There is no marked injury in these latter areas and the insect is extremely difficult to locate. Pea moths were not found in Cape Cove or Percé. The area around Barachois and St. George also appeared to be free of these insects.

Possible Factors Influencing Pea Moth Distribution on the Gaspe Coast

A detailed survey of the infestation in the St. Godfroi district yielded some interesting and significant information. Peas in this district are grown as far inland as the fourth range. Each range is about a mile in depth in this region and the farms are of the long, narrow-strip type. The third range is sheltered within a sloping valley and also protected by wooded areas located between this region and the sea. The severest infestations

FIGURE 1. Black areas indicate areas in which peas are grown in Gaspe County, P.Q.

FIGURE 2. Black areas indicate areas in which peas are grown in Bonaventure county, P.Q.

of pea moth have occurred in this sheltered area which makes up the third range. Peas on the first or shore range are considerably less affected by pea moth than those on either the third or fourth ranges. The cleanest peas have been grown on the shore range of Hope Town, which is very open and exposed to the influences of the sea.

There thus appears to be some reason for believing that the proximity of the sea exerts some influence that is not favourable for the most successful development and increase of the pea moth. Exactly what this factor, or factors, may be it is not yet possible to define with certainty. Wind, temperature, and humidity naturally suggest themselves as possible agencies of suppression.

An intimate knowledge of the picture of infestation in the St. Godfroi district proves valuable in attempting to understand the general range of pea moth infestation along the entire Gaspe coast. Taken in conjunction with other factors it enabled the writer to indicate the probable presence of the pea moth at Gaspe before it was actually located at that point, although Gaspe is about ninety miles from the nearest place where the pea moth had previously been definitely located. Both Gaspe and St. Marjorique are near the head of the Bay of Gaspe and thus rather sheltered from the extreme influences of the ocean encountered by those portions of the coast adjoining the open sea. It was concluded that the pea moth had been present on the coast for many years. It was also known to be present past the great natural barrier between Port Daniel and Chandler so that the insect had every opportunity of spreading through Gaspe county, unless climatic conditions were exerting a check on its advance in certain regions.

Cape Cove and Percé are to be found near the tip of the Gaspe Peninsula, where they are fully exposed to the influence of the sea. The country is open and with the ground rising in the back areas. The pea moth has not been found in these regions. It is also worthy of note that here the Colorado potato beetle frequently causes but little damage.

There are thus some indications that the pea moth requires a definite restricted range of environmental conditions in order for it to thrive to the extent of causing severe injury to its host plants.

Observations on the Life-history of the Pea Moth

Field observations were carried out during the season of 1936 to determine the life-cycle of the pea moth on the Gaspe coast. As the heaviest infestation of pea moth was centered around St. Godfroi most of the data secured were from this district.

The growing season of 1936 was later than former years and hence records of pea moth development for that year would likely tend to be later than the average. As these are the first records for the area, however, a definite comparison with previous years is impossible.

Careful surveys were carried out for evidence of activity of adult pea moths from the middle of June onward. Throughout July daily observations were made. Pea moth adults were finally observed, for the first time for 1936, on July 18 near Shigawake East in a garden patch of Tom Thumb peas. On July 19 the adults were found on both the third and fourth ranges of St. Godfroi district. By July 20 they were quite numerous and prevalent throughout the entire St. Godfroi district.

In connection with the first appearance of the adults it is interesting to note that they started to emerge on a day characterized by eleven hours of sunshine—the maximum for the two weeks period. The maximum temperature on the 18th was 71° F. but the minimum was 41° F.

Pea moth eggs were first observed in the St. Godfroi district on July 26. These were found on Tall Telephone peas growing on the third and fourth ranges. Eggs were located at many other points throughout the district on July 27. This might indicate a pre-oviposition period of about eight days but there was a series of dull days during the week following the initial emergence of the moths and many of these days were also quite wet. It is thus possible that oviposition may have been slightly retarded by weather conditions prevailing at this time.

On August 2 the first eggs (marked) laid by the pea moths hatched. This indicates an incubation period of about a week. However, the weather was not particularly warm during this period and it is reasonable to suppose that this time might be somewhat shorter with higher temperatures.

When the eggs are first laid they are whitish, but as the hatching time approaches they become darker (reddish) until finally the larva can be observed in the egg. The actual hatching process is usually quite rapid. The larva first splits the shell of the egg close to the head region. The insect is active from the moment of emergence.

By August 5 the adults of the pea moth were present in the St. Godfroi district and also eggs and larvae in various stages of growth. On the same day adults and eggs could be found near Port Daniel but no larvae. Also on the same day, adults could be found (scarce) around Anse au Gascon but no eggs or larvae could be located. Eggs of the pea moth were still hatching in the St. Godfroi district on August 13.

Pea moth larvae were first observed emerging from the pea pods during the third week of August. These were not numerous, however, and the main bulk of the worms were still in the pods by the first of September. The larvae appear to require about three weeks in which to become full grown. However, a larva may remain in the pod for some time after it has attained its maximum growth. Pea moth larvae could still be found in pea pods after the first of October where the pods had been picked early in September and left lying on the ground.

Moths were not observed after August 15. From the stage of growth of larvae recovered on September first there were indications that some eggs had been laid about the middle of August.

In the St. Godfroi district the main bulk of the pea crop had been picked and shipped by September first. At this time probably about 70 per cent of the pea worm population was still in the pods. This point appears to be of considerable importance from the standpoint of possible control through a vigorous clean up campaign.

The time of pupation of the pea moth is not yet definitely established. A few of the pea worms were still to be found in the pods on October 8. Records were not kept after that date as work on the Gaspe coast was suspended for the year on October 10. However, six hibernation plots have been laid out in St. Godfroi and it is hoped to get more information on this point in the spring of 1937.

In order to secure accurate data on emergence of the adults along the Gaspe coast plots have been infested with pea moth larvae over which cages will be placed next spring.

Habits of the Pea Moth

The pea moth adults are usually most active after about 4 o'clock in the afternoon, particularly on a warm, bright day. In flight they take a zigzag course and flutter in what appears to be a haphazard fashion among the pea vines. While they are resting on the pea foliage or in flight they are not ordinarily very hard to see as their lack of protective coloration, in relation to the pea plant, renders them somewhat conspicuous. However, when they are resting on the small trees used as supports for the peas their colours blend very well with the bark and the moths are then very difficult to locate. They do not appear to be very strong fliers.

FIGURE 3. Typical stand of peas illustrating cultural practice in vogue in the Gaspe.

The eggs of the pea moth may be laid on almost any part of the pea plant but the sepals appear to be a very popular location. Eggs occur on the leaves and stems and have also been observed attached to the flower petals.

From the time the egg shell is ruptured to the time the larva is actively marching over the plant the interval may be as short as 90 seconds. The newly hatched larva is an active insect and appears to be capable of covering considerable distances. The sepals and pod are sometimes thoroughly explored from end to end before the insect finally burrows into the pod. A common point of entrance is close to the back rib (hinge) of the pod.

It is quite common to find more than one larva in a single pea pod. As many as four to a pod have been observed.

The stage of growth of the caterpillars in the pea pod does not necessarily bear a direct relation to the age or general condition of the pod. Small and large worms have frequently been observed feeding within the same pod.

It is practically impossible to detect infested pods through examination of their external appearance. Empty egg shells on the sepals are of some slight assistance in this regard and it has been noticed that the sepals of infested pods frequently become dried and shrunken. Selection of such pods has been found to be no better than 50 per cent accurate. The entrance holes of the larvae are extremely hard to find.

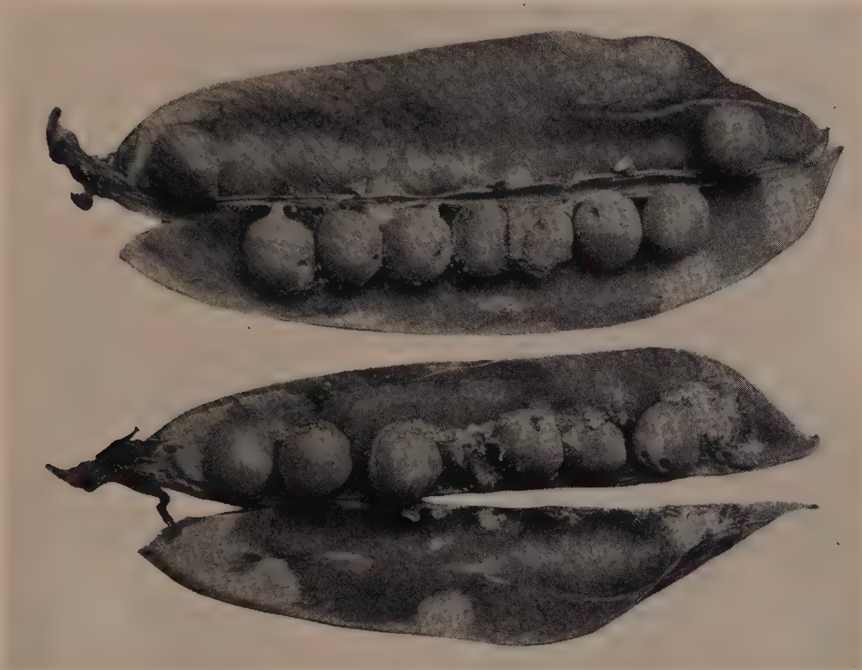

FIGURE 4. Infested pea pod showing two larvae and associated fungus infection.

While the larvae cause some webbing within the pea pod, the greater proportion of the unsightly appearance of infested pod contents is due to fungus growths Either the worms carry fungus spores directly into the pod interior with them or else they open up a channel for infection. The moist interior surface of the pod appears to be very favourable for fungus growth if entrance is once established. It is frequently possible to trace the spread of fungus growth directly to the entrance hole in the pod made by the pea worm.

The emergence hole in the pea pod is usually quite easily observed. It is usually in the side of the pod and very often close to the position of the individual pea seed that the worm happened to be feeding on just previous to the time it decided to emerge. The emergence holes also appear to be more frequently encountered in the distal half of the pea pod, indicating that the caterpillar during its feeding activities, may have a tendency to work downward within the pea pod as it grows older.

Up to the end of the first week of October, there was no sign of pupation in the autumn.

Control

The question of control has been, and is being, given attention. Tentative recommendations have been suggested which include improved cultural methods, and particular importance is attached to the probable value of a thorough clean up and disposal of all crop remains after the main bulk of the pea crop has been harvested. The growing of dried peas in the green peas areas is being discouraged. Plantings of peas on the back ranges of the St. Godfroi district has been automatically reduced through crop failures in those regions due to pea moth.

SUMMARY

The pea moth, *Laspeyresia nigricana* Steph., has been the cause of very severe injury to green peas on the Gaspe coast, particularly in Bonaventure county. The areas of infestation have been found to extend along all the cultivated shore regions of the county of Bonaventure and are directly linked with infestations in New Brunswick on the southern side of the Bay of Chaleur. In Gaspe county some important injury to peas by the pea moth has occurred in the vicinity of Chandler but this injury becomes evident later in the season than in Bonaventure county. The insect has also been located around St. Adelaide, at Grand River, at Gaspe, and at St. Marguerite. At these latter places there has been no injury of economic importance and the insects are, at present, very scarce.

Résumé

La teigne du pois, *Laspeyresia nigricana* Steph., sur la côte de la Gaspésie. A. D. Baker, Division fédérale de l'entomologie, Ottawa, Ont.

La teigne du pois, *Laspeyresia nigricana* Steph., a beaucoup abîmé les récoltes de pois verts sur la côte de la Gaspésie, spécialement dans le comté de Bonaventure. La région infestée comprend tout le littoral cultivé du comté de Bonaventure; le foyer d'infection est évidemment la rive sud de la Baie des Chaleurs, au Nouveau-Brunswick. Des récoltes de pois ont été attaquées dans le voisinage de Chandler, dans le comté de Gaspé, mais les dégâts s'y manifestent plus tard dans la saison que dans le comté de Bonaventure. L'insecte a aussi été signalé autour de St-Adélaïde, à Grande Rivière, à Gaspé et à Ste-Marguerite, mais il n'a pas causé de dégâts importants à aucun de ces endroits, et il y est très rare actuellement.

ARTIFICIALLY INDUCED FATUOIDS IN A DWARF MUTANT OAT[1]

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In a study of the probable origin of a semi-dwarf oat reported by the senior author in 1930 (3) and referred to as Trelle's Dwarf, an effort has been made by the use of X-rays and interspecific hybridization to bring about gene change or rearrangement. It is the purpose of this paper to report the appearance of a dwarf fatuoid form from X-rayed material and to relate certain genetic and cytological observations to its origin.

It is only within comparatively recent years that various forms of radiations have been made use of in the artificial production of mutations in plants. Plants representing widely different genera have been studied by many investigators, and with few exceptions the successful production of mutations of various types has been reported.

It is not proposed to review the literature on irradiation of plants in general and only brief reference will be made to those workers who have made contributions to the study of irradiation in species of Gramineae. Complete lists of references on all phases of irradiation are to be found in the recently published volumes edited by B. M. Duggar under the title *Biological Effects of Radiation*.

The effect of X-ray treatment on such crops as maize, wheat, barley and oats has been reported by numerous workers within the past few years. Radiations have been applied to dormant and germinating seeds, and to the immature flowers at or near reduction division. In other cases, flowers have been fertilized with irradiated pollen. Mutations have been induced by all the above methods, and while it is evident that the Gramineae are relatively susceptible to radiations produced by X-rays, the resulting mutant forms are, almost without exception, of no economic interest; in fact the great majority have been seedling chlorophyll deficiences or other abnormalities.

The following workers have reported mutations in Triticum species by X-ray treatment: Stadler (*10*, *11*, *12*), Delaunay (*2*), Sapehin (7, *8*, *9*), Yefeikin and Vasilyev (*13*), Katayama (*5*), and Afanassjewa (*1*). The appearance of speltoid and dwarf types, chlorophyll deficient seedlings, haploids and various abnormalities in chromosome complement have been noted. Strength of dose apparently determines to some extent the degree of abnormality.

Stadler (*11*) reported only one mutant in X-rayed *Avena sativa*, but other species of Avena with lower chromosome numbers were apparently more readily affected by the treatment and produced a larger number of mutations. Mutations in barley are more commonly induced by X-rays than in wheat or oats (Stadler *10*). The majority of these can be recognized in the seedling stage.

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[1] Paper read at the meetings of the American Society of Agronomy held in Washington, D.C., November, 1936, and published as Contribution No. 105, Cereal Division, Central Experimental Farm, Dept. of Agriculture, Ottawa.

[2] Cerealist and Cytologist respectively, Dominion Experimental Farms System, Ottawa, Canada.

Method Employed and Results Obtained

One hundred seeds each from normal, dwarf, and intermediate plants were germinated for 48 hours at room temperature. Young sprouts were just beginning to show at the end of this period. The dwarf and intermediate seeds were then divided into four lots of 25 seeds each, three of which were subjected to X-ray treatment for 5-, 10- and 15-minute periods. The dose given was 70 Kv., 5 m. a., at a distance of 12 inches without filters. The treated seed along with the control samples was sown in the Cereal Division greenhouse at Ottawa. The progeny of this greenhouse material consisting of about 2000 plants included eleven dwarf fatuoid mutants all from the dwarfs that had been X-rayed for 10 minutes. The original 25 dwarf seeds from the 10-minute treatment produced 332 seeds, and therefore the mutation rate for the fatuoid complex among the dwarfs from this treatment was over 3%. No evidences of other types of mutations could be detected in any of this material. The eleven fatuoids were identical with the parent dwarf form except that they possessed fatuoid characteristics, quite typical of homozygous fatuoids.

a *b* *c* *d*

Panicle types: *(a)* dwarf fatuoid mutant from dwarf *(b)* which was X-rayed; *(b)* dwarf; *(c)* intermediate; and *(d)* normal segregates from original type *(c)*.

In *(a)* of the accompanying figure is shown the panicle type of the dwarf fatuoid mutant induced by X-rays. In *(b)*, *(c)* and *(d)* are shown the three segregates (dwarf, intermediate and normal) from the original type heterozygous mutant *(c)* which in height and panicle shape was intermediate between the normal and dwarf forms.

A total of about 500 seeds was produced from the eleven dwarf, fatuoid mutants. These proved to be entirely homozygous for the dwarf and fatuoid characters except for three plants which were typical intermediates in so far as plant height and panicle shape were concerned; one carried dark lemma colour. It is improbable that the latter could have arisen through natural crossing since this material had been isolated from coloured varieties. The three intermediate plants appearing in the progeny of the fatuoid mutants showed some evidence of being heterozygous fatuoids.

Cytological studies of first meiotic divisions of the original dwarf, intermediate and normal segregates have shown the chromosome number to be normal (21 pairs) in all three forms. No irregularities were apparent in the normal segregates. In normal oats there is no terminally attached pair of chromosomes; the presence of a terminally attached bivalent in the dwarf form indicates deficiency or translocation of a chromosome arm. Quadrivalents were also quite frequent in the dwarfs. The occurrence of an occasional intermediate plant in the dwarf progenies favours the translocation and duplication hypothesis rather than that of deficiency. The presence, in the intermediate, of two associated pairs of chromosomes of different lengths to form a quadrivalent or trivalent and univalent further indicates that translocation of part of a chromosome has taken place.

While only preliminary studies have as yet been made on the chromosome behaviour of the fatuoid dwarf mutant, it appears certain that this form is more irregular than the parent dwarf. The junior author has unpublished data (6) which suggest that, in respect of the fatuoid complex, the *sativa* phenotype is produced as a result of the balance set up between *sativa* genes and the remainder of the genotype. The fatuoid phenotype is due to changes in this balance brought about through losses of *sativa* suppressors of the genes for fatuoid characteristics. There are two quadrivalents in the dwarf fatuoid. Since the fatuoid complex is allowed expression, it may be that one of the chromosomes involved in the second quadrivalent carried an inhibitor (or inhibitors) for the fatuoid complex.

Further genetic and cytological studies with this material are now in progress. Germinating seeds of the dwarf, intermediate and normal forms as well as the dwarf fatuoid mutant have again been subjected to X-ray treatment as a check on work reported above.

ACKNOWLEDGMENTS

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RASPBERRY NUTRITION

III. ARE SULPHATES DEFICIENT IN B.C. COASTAL SOILS?

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The decline of the Cuthbert variety of raspberry in coastal British Columbia continues to be a serious problem. At the present time rather extensive investigations are being carried out jointly and separately by University of British Columbia, Dominion, and Provincial authorities.

As a result of the work to date, much valuable information has been found which is more far-reaching than its application to the raspberry problem alone. It gives, for the first time, a true insight into the actual soil conditions prevailing in many sections of British Columbia. While little or none of this information would come under the category of new discoveries peculiar to coastal British Columbia, it does, however, reveal

FIGURE 1. Outside plants grown in sterilized soil. Centre plants grown in same soil unsterilized. (Photograph by J. J. Woods.)

conditions which were either unsuspected or not appreciated by the growers. For example, work done in the Plant Nutrition Laboratory of the Horticulture Department of the University of British Columbia has shown the seasonal trend of available nutrients in coastal B.C., and so given us a guide for general fertilizer practices (7).

It has been found, also, that a number of prevailing conditions could be responsible for failure of crops—namely, marked soil deficiencies of nitrogen, calcium, phosphorus and potash, brought about by loss of organic

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matter from the soil and the resulting loss of power of the soil to hold minerals against leaching losses during the somewhat heavy winter rains. Excess acidity, "wet feet", and poor drainage conditions, and in some cases an unbalanced nutrient supply due to improper fertilizer practices are all conditions to be found in certain areas (8). That winter injury to the Cuthbert variety is a serious factor has long been recognized.

This list does not preclude other probable causes of failures.

It was suspected that soil organisms, including parasitic fungi, may be partially responsible for the trouble, especially in view of a preliminary survey made by Jones (9). In order to support this view, Woods conducted an experiment at the Dominion Experimental Farm, Agassiz, to note the effect of soil sterilization on the growth of raspberry plants in soil which it was known otherwise would not grow them satisfactorily. The experiments were carried out in 12-inch clay pots. One-year-old raspberry plants were used. One-half of the series of plants was planted in steam sterilized soil, the other half was planted in the normal or unsterilized soil.

The difference was marked. By the end of the growing season the plants in the sterilized soil were about six times larger, more vigorous and healthy than those in the unsterilized soil. The latter were stunted, weak plants showing similar symptoms of decline to plants growing in the area from which the soil was taken.

From the above it would appear that harmful organisms or pathogens were responsible for damage in the unsterilized soil. These were killed by the soil sterilization, hence the good growth in the sterilized soil.

In view of the previous work in this laboratory, which demonstrated the prevailing nutrient deficiency condition in the coastal area due to leaching losses (8), it was concluded, however, that there was also the possibility that available nutrients may have been increased due to chemical changes in the soil caused by the sterilization. Darbshire and Russel state that such changes do take place (5).

MATERIALS AND METHODS

With this possibility in mind, samples of soil from the sterilized and unsterilized pots were sent to the horticultural laboratories at the university, where they were analysed for available nutrients, using the same method of procedure as outlined by Harris and Woods in a previous report (7).

The displacement method of Burd and Martin was used to obtain the soil solution (4). This method had been found particularly satisfactory in previous work. The results of these analyses follow.

Determinations were made on the displaced soil solutions for the following: nitrates, phosphorus, potassium, calcium, sulphates, magnesium, manganese, pH, electrical resistance, organic matter, aluminum and iron.

RESULTS

The following table shows a comparison of the displaced soil solutions from the sterilized and unsterilized pots after one season's growth of raspberry canes in them.

TABLE 1.—A COMPARISON OF AVAILABLE NUTRIENTS IN STERILIZED AND UNSTERILIZED SOILS

Soil sample	Electrical resistance in ohms	pH	Materials analysed for in parts per million					
			Nitrate	Phosphate	Potassium	Calcium	Magnesium	Sulphate
A Normal	820	5.85	20	1.9	22	67	5.5	4.5
A Sterilized	738	5.95	70	1.8	31	79	9.0	10.8
H Normal	618	5.40	120	0.1	19	96	5.5	3.8
H Sterilized	550	5.30	190	0.5	35	112	11.0	21.0
D Normal	698	6.15	17	2.0	19	82	4.5	2.0
D Sterilized	525	6.15	135	2.0	26	142	17.0	23.0
P Normal	615	5.80	83	0.1	16	78	4.8	7.0
P Sterilized	515	5.75	140	1.7	20	157	18.5	25.0

The outstanding feature of Table 1 is that the sterilization of the soil in each case increased the total available minerals as shown by the electrical resistance (the less the resistance the greater the concentration of minerals), as well as all individual ions analysed for, except phosphates (PO_4). While organic matter is not shown in the table, due to relative qualitative figures only being obtained, it was especially noteworthy that on evaporating aliquots of the solutions to dryness, without exception heavy precipitates of organic matter were present in the soil solution from the sterilized soil, in contrast to little or none in the solution from the unsterilized soil.

The pH was not appreciably affected by the sterilization. The increase in nitrates was marked, potassium appreciably so. The percentage increase in the sulphate was large. In Sample D it increased 12 times the amount. The results are so striking that further comment is unnecessary. Phosphates do not show a consistent increase due to sterilization. The amounts are relatively small in all cases.

Qualitative tests made by Spurway (18) and Morgan methods (13) for iron and aluminum are not shown in the table, as it was felt that the methods used were not sufficiently reliable to warrant drawing any conclusion, especially as the amounts and differences were small and results inconsistent. Manganese, as determined by the Luhrig method (12) was so small in amounts as to lead one to suspect a manganese deficiency in these soils. The sterilized soil alone showed a detectable significant amount.

DISCUSSION

The results definitely show that soil sterilization does affect the availability of plant nutrients, in this case markedly increasing them. That

increased growth in the sterilized soil could be a result of the sterilization increasing available nutrients would seem a justifiable conclusion.

While organisms are undoubtedly involved in the increased production of nitrates and the sterilization created conditions favourable for their increased nitrate production, Russel and Hutchinson (15) also found that the heat of sterilization decomposes humus, which must also be a step in making nitrogen more available for plant use.

The data is in accordance with Russel and his co-workers (5, 15, 16) and Elvedin (6), who found that the increased productivity of a sterilized soil is in no small measure due to a change in the chemical composition of the soil.

The increase in the availability of the three replaceable bases, potassium, calcium and magnesium gives rise to some interesting speculations. It is difficult to tell whether sterilization caused chemical changes to increase the concentration of these three elements by decomposing soil mineral or not. Possibly sterilization caused a large increase in one of these elements, *e.g.*, potassium, which in turn replaced some of the other two, making them more available.

The concentration of phosphorus did not appear to differ vary much between normal and sterilized soils. Russel (15) showed that plants in sterilized soil take up more phosphorus than the plants in normal soil. Thus there was in all probability more phosphorus available in the sterilized soils during the growing season. Certainly the large, vigorous plants in the sterilized soil would consume greater amounts.

There seemed to be little or no effect of sterilization on the availability of iron and aluminium, but as mentioned previously, semi-quantitative methods only were used in making these determinations.

Manganese was present in such small amounts that one would hardly expect the beneficial effects of sterilization to be due to increased manganese availability. According to Olsen (14) this element is not likely to be absent in acid soil. Nevertheless, a suspicion of manganese deficiency is created.

The large increase in sulphate is considered very significant. The plant symptoms in the unsterilized soil resembled the description of yellows by Storey and Leach (19).

Furthermore, there seems to be ample evidence that an increased sulphate content increases the available phosphorus in the soil (3, 10, 11). Rudolfs (17) also claims that sulphates can liberate potassium. If so, it is possible that sulphates can liberate the other replaceable bases, calcium and magnesium, and as before stated, these could, in turn, be liberated by the potassium.

Indirectly, the increase in sulphate in the sterilized soils may be the cause of the general increased fertility of this soil, and the soils on the farms showing raspberry decline may through their low sulphate content be lacking in general fertility.

Brown (1 and 2) showed that sulfofication or sulphur oxidation is very important, as most sulphur in soils is present in unassimilable organic and inorganic compounds. It therefore appears that it is the ability of a

soil to produce sulphates from these unavailable substances which will determine very largely the sulphate content and the secondary sulphate effects in the soil. Thus the sulfofying powers of the raspberry soils of the Fraser Valley in British Columbia may be low, and hence a partial cause of the failures.

The question of low organic matter is significant, and has been previously referred to in other reports (7 and 8).

GENERAL CONCLUSION

The following is deduced from the complete investigation to date, for which evidence other than in the above paper has been reported.

The raspberry decline problem in British Columbia is due initially to loss of organic matter (often through faulty management practices) with the resulting loss of ability of the soil to hold nutrients. This results in heavy leaching losses and starvation effects, giving weakened plants. A sulphate deficiency, with its ramifications, is accentuating the trouble. The cuthbert variety of raspberry is not particularly hardy at the best, and in its weakened condition is affected by winter injury, which further weakens the plants. The weakened plants are finally attacked by semi-parasitic root rot fungi of various species (mostly native to the soil). Root rot fungi of cylindrocladium species native to the soil are quite prevalent. These fungi will not attack a healthy, vigorous plant, but apparently do attack a plant in a weakened, unhealthy condition, and so contribute finally to its death.

SUMMARY

Sterilization of soil from raspberry plantings where decline is prevalent in British Columbia results in a general increase in fertility, because several plant nutrients and organic matter are made more available. The change in sulphate content appears to be very significant because the increase is so great that there is a possibility of very beneficial secondary effects.

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